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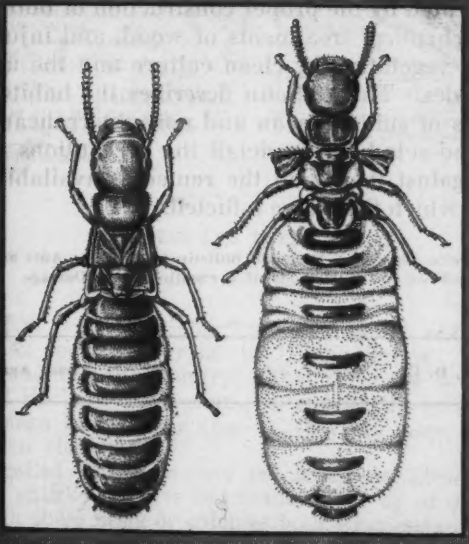
PREVENTING DAMAGE BY TERMITES OR WHITE ANTS



THROUGHOUT the United States native termites, or white ants, cause serious damage to the foundations and woodwork of buildings and articles in the buildings, as well as to living fruit and other trees, crops, and other vegetation. Such damage can be prevented by the proper construction of buildings and by chemical treatments of wood, and injury to growing vegetation by clean culture and the use of insecticides. This bulletin describes the habits and activities of subterranean and nonsubterranean termites and sets forth in detail the precautions to be taken against them and the remedies available for damage which they have inflicted.

This bulletin supersedes Farmers' Bulletin 1037, White Ants as Pests in the United States and Methods of Preventing Their Damage.

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PREVENTING DAMAGE BY TERMITES OR WHITE ANTS

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TERMITES AND THEIR HABITS

DISTRIBUTION AND FORMS

TERMITES, or "white ants," are destructive native insects of which 42 species occur in the United States. They are distributed throughout the country, although in the southern, southwestern, and Pacific coast regions, where both the subterranean and nonsubterranean kinds occur (fig. 1), they are more numerous and injurious than elsewhere.

These so-called white ants are not true ants, although they are superficially antlike and live in colonies made up of different forms or castes. In these nests or colonies both wingless and winged mature individuals are produced. The brownish or blackish, elongate, slender, antlike, colonizing, sexual adults (fig. 2) with long white wings, unlike the other forms, have functional eyes and their bodies are able to endure full sunlight. These migratory males and females appear normally once a year during a short period. There are three stages in the life of white ants: The egg, the immature form (nymph), and the mature individual (including sterile workers (fig. 12, *b*), soldiers (fig. 12, *a*), and the various fertile reproductive forms).

LOCATION OF COLONIES OR NESTS

The nests of some species of termites [1] are in the earth and in dead and decaying wood. These species are of subterranean habit, timber and trees being attacked by the workers only through the ground. The nests of some other species,[2] however, are excavated in wood and trees by the winged forms, there being no workers and no underground life.

With the clearing of land and the consequent destruction of their natural breeding places in the dead trees, decaying stumps, and logs of the forests, termites become increasingly destructive to the woodwork and contents of buildings (figs. 3–9), telephone poles, fences, or any timber in contact with the ground, as well as to living vegetation, including not only fruit and shade trees, shrubs, and flowers, but also truck (fig. 10) and field crops and, in California,

FIG. 1.—Map showing distribution in the United States of nonsubterranean wood-boring termites (Kalotermes and Cryptotermes). The dots indicate localities from which the Bureau of Entomology has records of occurrence or damage. The group of termites of subterranean habits (Reticulitermes, etc.) is much more widely distributed, being represented in practically every part of the United States

grapevines. The principal food of termites is cellulose, which they obtain from either dead or living vegetation.

Termites in the United States are mainly species of subterranean or wood-boring habit and are not so spectacular or common as the mound-making or tree-nesting termites of the Tropics. Very few termites in this country have habits which make them conspicuous, or come above ground into the sunlight, except during the annual colonizing swarm; hence they largely escape notice until they become injurious.

TERMITES WHICH ARE SUBTERRANEAN IN HABIT

Subterranean termites live in forests, building their nests in the wood of standing timber, logs, or stumps, in cleared land, any wood

[1] Genera Reticulitermes Holmgren, Leucotermes Silvestri, Amitermes Silvestri, etc.
[2] Genera Kalotermes Hagen, Neotermes Holmgren, Cryptotermes Banks, etc.

in contact with the ground or, in the plains, in a labyrinth of underground passages in the earth, usually underneath wood or vegetation.

Termites are soft-bodied and always conceal themselves within wood, in the earth, or within their earthlike carton shelter tubes (fig. 11). The grayish-white, soft-bodied, wingless, sterile "workers" (fig. 12, *b*) are in reality the destructive form. These workers make the excavations occupied by the colony and enlarge and extend them as the colony increases. They live underground or within the wood, are blind, and shun the light; as a result they are rarely seen. In burrowing through wood the workers often completely honeycomb it, usually following the grain and eating out the softer, thin-walled, larger-celled spring or new wood. They are able to penetrate the hardest of woods, provided they have access to moisture in the ground. In extending their galleries in wood and vegetation, subterranean species carry moisture with them by means of moist excrement mixed with earth.

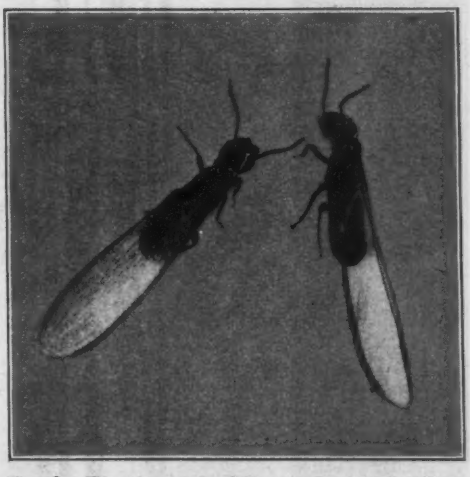

FIG. 2.—Winged sexual adults of an eastern subterranean termite, *Reticulitermes virginicus*. Nearly six times natural size

TERMITES WHICH ARE NONSUBTERRANEAN IN HABIT

The nonsubterranean termites which are injurious attack wood directly; but, instead of following the grain continuously, they excavate through it longitudinal chambers of limited length. The sexual adults, after they have lost their wings, and the young or nymphs, are the destructive forms. Their pellets of excrement (fig. 13) are regularly impressed, and sometimes completely fill or block up the burrows in a compact mass; they are often expelled as dry droppings from the infested wood. These termites are destructive to the woodwork and furniture in buildings (figs. 14, 15), as well as to living trees. Apparently they can exist without the great amount of moisture necessary to the life of termites which are subterranean in habit.

THE COLONIZING SWARM

At certain seasons, usually spring or fall, but varying with the species and the locality, the winged, sexual individuals migrate in large numbers from the parent nests. They then lose their wings and breed new colonies. In the case of the subterranean termites, wood and trees are usually entered indirectly through the ground,

although sometimes these insects enter trees under bark loosened by sunburn, etc., or through scars or borer holes, provided sufficient moisture is present. Nonsubterranean termites enter the wood directly, or, in the case of trees, through wounds or borer holes or under loose bark; moisture is not necessary.

FIG. 3.—Damage to oak flooring by the common eastern subterranean termite *Reticulitermes flavipes*. Note that damage is not apparent on upper surface

In the new quarters eggs are laid, the young develop, and in a few years the colony increases in numbers, and the "workers" are able to feed and care for the reproductive forms—the "king" (title page, left) and "queen" (title page, right)—as well as the soldiers (fig. 12, *a*), which are sterile forms adapted to protect the colony from insect enemies, notably the true ants. In recently formed young colonies the rate of egg laying is slow, but mating is repeated, and, although there is at first a gradual increase, later the increase in the numbers of the broods is rapid. In old colonies there are thousands and tens of thousands of individuals.

Egg laying occurs over a considerable period during the warm months in colonies out of doors. In infested buildings artificially heated, where an even temperature is maintained, the insects are active and may lay eggs every month of the year. The number of eggs laid depends on age.

THE REPRODUCTIVE FORMS

Owing to the increasing number of eggs that develop within her, the queen becomes enlarged, but never loses the power of locomotion. It was once believed that, since the queen mother was the source of the colony life, the termite colony would be exterminated if she were destroyed, but this has been disproved by more recent studies. In addition to the forms that have shed their wings, several different types of reproductive forms occur—forms with wing pads (the undeveloped wings of the nymphs) and wingless reproductive adults. The winged forms, however, are the normal type and occur as a single pair, whereas there may be hundreds of the other forms heading colonies. The reproductive forms with wing pads and the wholly wingless type usually have little color to the body, and the eyes are small. These forms rarely come above ground or leave the burrows in wood.

FIG. 4.—Quartered-oak flooring damaged by the subterranean termite *Reticulitermes flavipes* in an infested building, Washington, D. C., 1915

The location of the queens in the colony depends upon the season of the year. During periods of intense heat or drought in the plains or in arid or prairie regions the subterranean termites burrow deeply below ground or to a less depth under stones, cow chips, etc. During winter in the colder climates they burrow below the frost line.

Whole colonies of subterranean termites migrate when conditions become unfavorable. The nonsubterranean termites, on the other hand, are not able to leave the wood in which they have excavated their nests.

PREVENTING AND REMEDYING DAMAGE TO WOODWORK OF BUILDINGS

DESTRUCTION OF BREEDING PLACES ABOUT THE BUILDING SITE

If buildings are to be constructed on recently cleared woodland, decaying logs and stumps should be removed from the soil in the vicinity and burned. If, because of the presence of decaying wood and humus, the subterranean termites are numerous in the earth, the soil should be deeply plowed or otherwise broken up and treated with chemicals to kill the insects. Effective poisons for this purpose are sodium cyanide;[3] a 10 per cent solution of sodium arsenite; kerosene oil; 1 part coal-tar creosote and 3 parts kerosene oil (this mixture should be strained through burlap before use); carbon-disulphide emulsion, which is on the market ready for use; orthodichlorobenzene; lye; or other contact poisons or gases. Live steam forced into the soil will serve the same purpose as the gases. Decaying fence posts, sidewalks, etc., should be removed and replaced with treated wood, concrete, stone, or other resistant substances; such decaying material would facilitate the formation or perpetuation of the termite colonies.

FIG. 5.—Tube of coarse yarn from bale of cotton on floor of building infested by subterranean termites, Greenville, S. C.

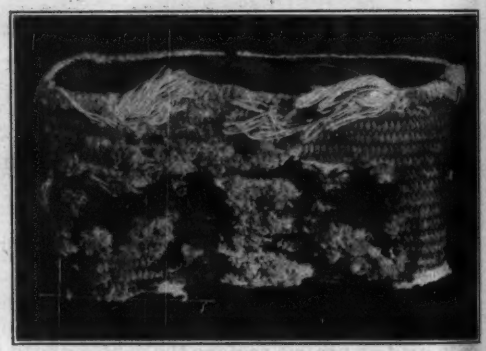

FIG. 6.—Cotton jacket of rubber-lined fire hose from infested building in Missouri, damaged by subterranean termites (*Reticulitermes* sp.)

PROPER CONSTRUCTION OF BUILDINGS

Termites will infest not only old buildings but also improperly constructed new buildings, and these are often badly infested. It is not the age of the building but the manner in which it has been constructed that renders it liable to attack.

Insulation.—Complete insulation from the ground of all untreated woodwork of buildings is the only effective permanent remedy

[3] For each acre to be treated, dissolve 160 pounds of granular sodium cyanide in 12,000 gallons of water.

FIG. 7.—Revenue stamps damaged by the subterranean termite *Reticulitermes flavipes* on infested flooring in the Bureau of Engraving and Printing, Washington, D. C., 1921

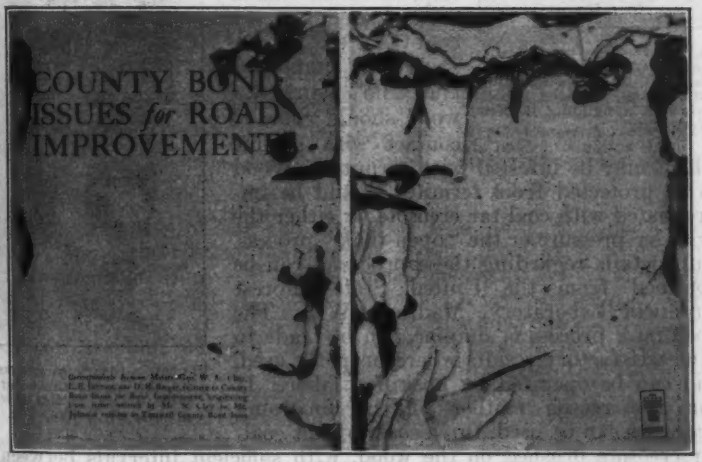

FIG. 8.—Correspondence and advertisement regarding issue of county bonds; damaged by subterranean termites infesting the building in Virginia in which they were stored

against attack by subterranean termites, and the only relief from their presence. These insects must maintain contact with the ground to obtain the moisture necessary for their existence. When contact with their moisture supply in the earth is cut off, the subterranean insects in the damaged wood, no matter how numerous, soon dry up and die.

FIG. 9.—Damage by the subterranean termite *Reticulitermes flavipes* to shoe stored on infested woodwork in a building in New York City

Foundations, supports, etc.—To prevent subterranean termites from reaching the woodwork of buildings from their nests in the ground, the foundations of buildings should be constructed, if possible, entirely of stone, brick, concrete, or concrete and steel,[4] including the pillars in the basement or cellar. The walls, partitions, and flooring in the ground floor, basement, or cellar should also be of concrete. Wooden flooring can be laid over this concrete floor if desired. If the flooring is to be of concrete, the concrete should be laid on a gravel base.

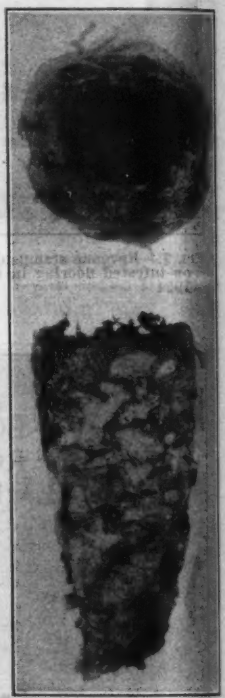

FIG. 10.—Injury to carrots by the subterranean termite *Reticulitermes claripennis*, at Dallas, Tex.

In buildings where stone, brick, or concrete foundations are impracticable, timber impregnated with coal-tar creosote should be employed, and no untreated wood should come in contact with ground which may be infested with termites. Wood to be protected from termites should be impregnated with coal-tar creosote by either the cylinder-pressure or the "open-tank" process. Full details regarding these processes can be obtained from the United States Forest Products Laboratory, Madison, Wis. The open-tank process is simpler, can be made to give satisfactory results where properly used, and can be operated by unskilled labor. If for any reason neither of the foregoing processes can be used, three coats of hot coal-tar creosote brushed on the wood, with sufficient intervals between brushings to permit each coat to dry, will be fairly effective. This

[4] In the Southern States, especially in the subtropics, the more valuable permanent buildings should be constructed entirely of steel and concrete.

method, however, is not generally recommended, since it will preserve the wood for only a few years.

The supports of porches or steps should never be laid directly on the ground, but should rest on rock or concrete. Window sills and frames in the basement or cellar should be laid over concrete and the woodwork should not come in contact with the ground. The supports of the woodwork of coal bins in basements or cellars should not be set in the ground, but should rest on concrete, not extending through the concrete into the soil.

Concrete flooring.—Even in permanent stone or concrete and steel buildings the concrete flooring is often constructed improperly.

FIG. 11.—Carton, earthlike, shelter tubes constructed by the eastern subterranean termite *Reticulitermes flavipes* over brick wall in dark, heated, damp basement; these tubes are used in passing over impenetrable substances. Inset, near view of tubes to show texture

Usually the base of the concrete floor is a loose combination of coarse gravel or cinders and cement grout. This very rough conglomerate, even if several inches thick, has many cracks and large holes running through it. Over this is laid a layer of solid concrete about 2 or 3 inches thick, of fine texture, in which untreated wooden sleepers are laid while it is still moist. These sleepers nearly or quite reach the coarse, open conglomerate in contact with the earth, and to them is nailed the wooden flooring. (Fig. 17, A.)

It will be seen that this is faulty construction. Termites have free access from the earth, in which they have galleries, through the porous conglomerate, to the untreated beams and flooring. *There should be a layer of solid concrete at least 1 inch thick between the grout and the wood.* (Fig. 17, B.)

Among the commonest means of infestation are wooden sleepers or stringers laid in concrete while the latter is still soft, or placed before the concrete has been poured in. Termites enter through these wooden beams. Other common means of infestation are supports of coal bins extending through concrete and through the disintegrated lime mortar of brick walls.

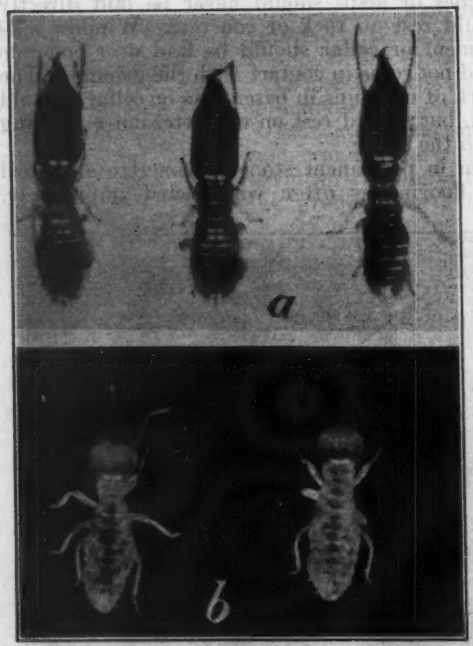

FIG. 12.—Mature soldiers (*a*) and mature workers (*b*) of the eastern subterranean termite *Reticulitermes flavipes*. Slightly more than six times natural size

Termite shields, guards, or metal caps.—The most injurious termites in this country are subterranean in habit and require constant access to the earth in order to attack wood which is either in contact with the earth or which they reach through covered, earthlike shelter tubes constructed over the face of stone, concrete, or brick foundations. In consequence they can be kept out of buildings by means of metal barriers. By simply inserting a sheet of galvanized iron or "termite shield" into the masonry and turning the projecting edges downward at an angle, communication of termites with the earth, where they obtain moisture, can be cut off. In less pretentious frame buildings, metal caps are placed over the tops of construction stone piling or pillars, or wooden supports.

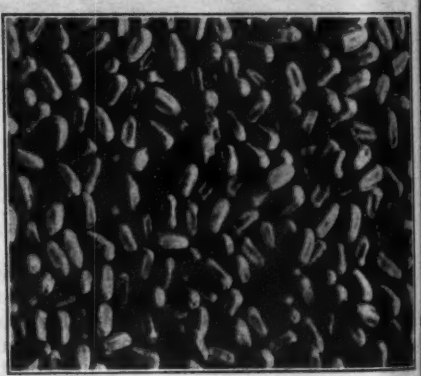

FIG. 13.—Impressed pellets of excrement of nonsubterranean termites (*Kalotermes* sp.), which drop from infested wood. Greatly enlarged

This is a similar method to that used in rat-proofing corn cribs. It is effective and practicable where untreated timber is placed over masonry foundations.

Again, in the case of stone and steel buildings, the steel or stone pillars or piping extending down through the concrete floor to foundations in the earth often make infestation possible, owing to the fact that the concrete floor does not fit tightly about them. Overlapping strips of metal extending horizontally several inches from the pillars or pipes should be imbedded in the concrete floor in order to obtain a tight joint (fig. 17, B); or liquid (adhesive) asphalt should be poured in to plug up the crevice or frame.

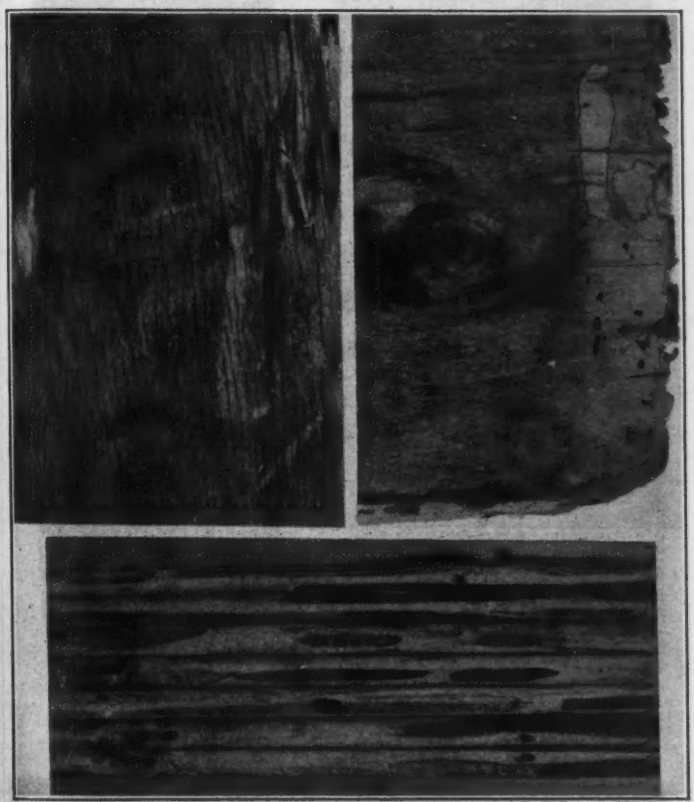

FIG. 14.—Bottom of bureau drawer damaged by the nonsubterranean wood-boring termite *Cryptotermes brevis*, which occurs at Key West, Miami, and Palm Beach, Fla.

Avoiding dampness.—Complete dryness of foundation timbers and basement walls and flooring is an important aid in rendering buildings safe from attack by termites. Dampness, warmth, and darkness attract these insects. A deep air space should be left between the ground and wooden flooring, unless, as in factories, heavy trucking is to be used over the floor, in which case this is impracticable. An air space should be left between the concrete floor and the wooden floor laid over it. Concrete floors should be laid on a gravel

base, which will prevent dampness and cracking. The points of juncture between concrete walls and wooden flooring should be filled in by rounding off the concrete at these places, since cracks often occur where the wall and floor join at right angles. (Fig. 17,

FIG. 15.—Furniture damaged by the nonsubterranean, wood-boring termite *Cryptotermes brevis*, Key West, Fla.

B.) Termites often come up through cracks between walls and flooring.

By mixing a heavy mineral residual oil with Portland cement, a material is formed almost perfectly nonabsorbent of water and therefore excellent for use in damp-proof construction. Where the

various patent or noiseless floorings are used on the ground floor they should always be laid over a concrete base, especially if they contain wood fiber as a constituent.

In no case should beams be completely surrounded with mortar or brick; there should be a space around them sufficient to permit air circulation. Beams should not be set in earth or in moist concrete, but on rock or dry concrete, or in grooves in the latter.

Bungalows or frame buildings which have no cellar should be raised from the ground on stone, concrete, or brick foundations to a height which will allow light and air to penetrate beneath.

Avoiding lime mortar.—In brick walls, where lime mortar is used, this sometimes disintegrates after a few years and termites penetrate through the spaces thus left between the bricks, especially where the brickwork is below the ground level. (Fig. 16.) Such walls should be faced with Portland cement 1 inch thick, especially if untreated wood is to come in contact with the bricks.

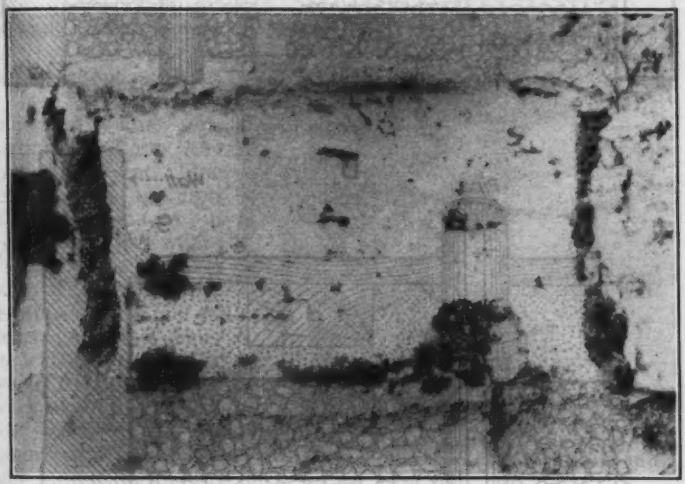

FIG. 16.—Interior view of portion of whitewashed brick foundation wall of building, below ground level, showing shelter tubes of our common subterranean termite (*Reticulitermes* sp.) penetrating the disintegrated lime mortar. These termites came through the earth banked up against the exterior wall. To remedy this condition the exterior wall will have to be faced with concrete for some distance below the ground level

Use of chemically treated wood for interior woodwork, furniture, etc.—In the Southern States, especially in the subtropics, in the more valuable permanent buildings the interior woodwork, furniture, etc., should be impregnated with preservatives, since nonsubterranean termites that attack wood directly are common in those regions. Zinc chloride, bichloride of mercury,[5] sodium fluoride, and chlorinated naphthalene[6] are effective preservatives.

[5] The extremely poisonous character of mercuric chloride renders its use dangerous. It is slowly volatile, and there is a possibility that it will be given off continuously in small quantities from the treated wood. However, it has been extensively used in Germany and apparently without serious consequences.

[6] This preservative is usually referred to as trichlornaphthalene and, as compared with other chemicals, it is really comparable to a technical product having naphthalene, monochloronaphthalene, dichlornaphthalene, and probably some of the higher chlorinations as impurities. Its melting point ranges between 190 and 210° F.—the specification under which it is sold.

Wood-pulp products, such as the various wood-fiber processed or composition boards, or cane-fiber boards, for interior finish and substitutes for lath (fig. 18), or for exterior use, can be protected from attack by termites by adding certain poisons, such as crude carbolic acid, to the pulp or laminated boards in the course of manu-

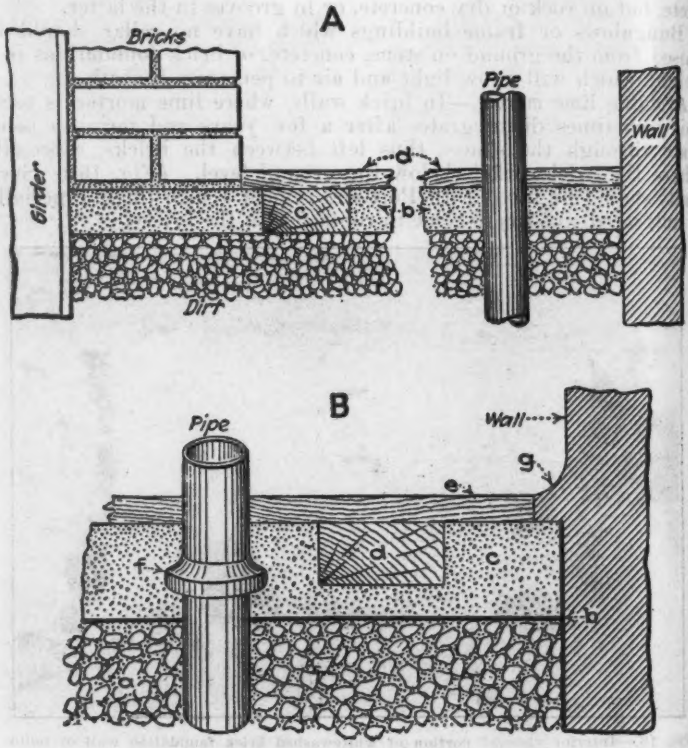

FIG. 17.—A, Improperly constructed concrete flooring: *a*, Gravel or cinders loosely cemented with coarse concrete, 3 inches thick, but with many crevices and holes; *b*, solid, dense concrete, 2 inches thick; *c*, 2 by 4 inch untreated wood sleeper set in moist concrete over the grout; *d*, ⅞-inch pine flooring nailed to sleepers. B, Properly constructed concrete flooring: *a*, Gravel or cinders loosely cemented with coarse concrete, but with many crevices and holes; *b*, asphalt waterproofing ⅛ inch thick; *c*, dense concrete, 3 inches thick; *d*, 2 by 4 inch wood sleeper set in a groove in concrete which insulates it from termites in the earth; *e*, ⅞-inch flooring nailed on sleepers; *f*, metal collar around pipe which runs down through the concrete (this collar should be soldered to the pipe and embedded in the concrete); *g*, shoulder of concrete at point of wall and concrete floor to avoid a right-angle connection and consequent cracking

facture. Available poisons for this purpose are crude carbolic acid at the rate of 1 gallon to 1,000 square feet; bichloride of mercury at the rate of 49 ounces per 1,000 square feet; or copper sulphate at the rate of 113 ounces per 1,000 square feet.

MODIFICATIONS OF CITY BUILDING CODES

One of the simplest and most effective means of prevention of attack would be to modify the building regulations or codes of various cities so as to include a few simple rules to protect houses from damage by termites. As the principal object in view is to keep all untreated wood from contact with the ground, where the termites live and from which they get their moisture, the regulations should stipulate that no floors, sills, beams, clapboard, etc., of untreated wood may be laid on or in the earth, and that untreated beams may not be laid in concrete without at least 1 inch of concrete underneath and separating it from the earth; that no lime mortar may be used in foundations or in cellar walls where they are in contact with the earth, since termites are able to penetrate lime mortar[7] after some years' service; that all brickwork extending below the surface of the ground shall be faced and capped with concrete at least 1 inch thick; and, where nonsubterranean as well as subterranean termites occur, that only woodwork impregnated with preservatives be used for exterior and interior construction, unless it is impracticable to obtain such treated wood.

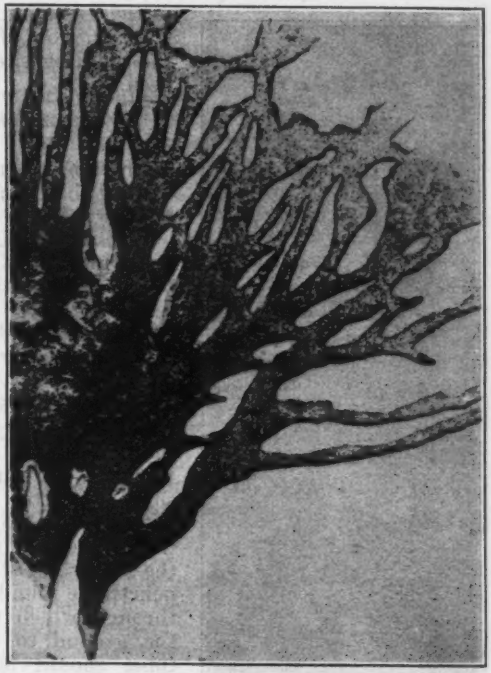

FIG. 18.—Pressed wood-pulp tile mined by subterranean termites infesting the building, Biloxi, Miss.

LOCATING AND TEMPORARILY ARRESTING THE DAMAGE

Although it may be difficult to eliminate termites and stop further damage by them, when once these insects have become established in the woodwork of a building, the approximate point of entrance should be sought at once by careful examination of all woodwork in contact

[7] The Bureau of Standards of the United States Department of Commerce recommends a mortar composed of 1 part Portland cement to 3 parts of sand graded from fine to coarse, with no grains larger than will pass through the No. 10 sieve, to which may be added 10 per cent by weight of the cement of some workability agent, such as hydrated lime, for use in locations where termites abound. Such a mortar, it is believed, will have the desirable properties of both cement and lime mortars and, furthermore, will contain a sufficient quantity of cement to prevent the penetration of it by the termites. (See fig. 16.)

with the ground. To do this, it may be necessary to tear up the foundations, flooring, and some other woodwork. The foundation timbers and interior woodwork found damaged should be removed, and the ground where they were set should be broken up and drenched with some liquid which will kill or at least temporarily prevent the further activity of termites at that point. Any of the insecticides[8] mentioned under the heading "Destruction of breeding places about the building site" (p. 6) will meet the need.

FIG. 19.—Entrance holes of sexual, colonizing adults of a nonsubterranean termite (*Kalotermes hubbardi*) in wood of dead cottonwood tree in Arizona

INDICATIONS OF INFESTATION

The annual emergence of large numbers of the flying termites is an indication as well as a warning that the woodwork is infested, and the point of emergence indicates the approximate location of the infested timbers. Even if the insects are not observed "swarming," large numbers of the dead winged adults or of the discarded wings usually will be found near by. Frass and earth thrown out of crevices through which the insects emerge are also evidences of their presence. Another warning is the presence of branching shelter tubes of small diameter, made of earth mixed with finely powdered wood, on foundation timbers or other woodwork, or over the surface of stone, brick, or other impenetrable foundation material (fig. 11), through which the insects travel from the ground to the woodwork. These tubes should be broken off and the ground where they originate broken up and drenched with one of the liquids named in the paragraph under the heading, "Destruction of breeding places about the building site" (p. 6).

In the case of the nonsubterranean termites, which infest wood directly, evidences that they are damaging wood are the impressed pellets of excrement (fig. 13) which are expelled from the wood. Other evidences are the holes, similar in size to BB shot, where the insects entered the wood. (Fig. 19.)

KILLING THE WINGED ADULTS WILL NOT STOP THE DAMAGE

When efforts are made to prevent further damage by termites in buildings, it should be realized that the numbers of these insects may be constantly recruited from some undiscovered, outside, central colony. The destruction of the winged colonizing adults with house-

[8] If sodium cyanide is used, a strong solution, 1 ounce to a gallon of water, is desirable.

hold ammonia, etc., at the time of emergence, although beneficial in preventing the establishment of new colonies, will not eradicate the insects infesting the woodwork. The most destructive forms are the white, wingless workers, which remain within the wood.

DISCONNECTING WOOD FROM THE GROUND

Subterranean termites infesting beams or other wood will die out if the wood is disconnected from the ground. Knowledge of this fact will save time and expense, especially in the case of old frame buildings, where extensive repairs would be unwarranted. Disconnecting untreated foundation timbers from contact with the soil will also cause the death of subterranean termites in the other woodwork, furniture, and stored material in the building, even if they have penetrated to the second or third floors. These timbers need not be removed or replaced unless seriously weakened structurally. However, if the wood is kept moist by some other means, such as water leakage, the termites will continue to work and thrive. This applies especially to damp corners of basements near outside water pipes, bathrooms, kitchens, and the like.

Wooden floors laid directly on the ground or on stringers on the ground, or set in concrete, should be removed. There should be a layer of concrete between the earth and the wooden floor (fig. 17, B). Wooden baseboards should be removed.

REPLACING WITH CONCRETE

Concrete floors and concrete baseboards should be substituted for wood. Untreated beams penetrating through concrete floors into the earth and the lower parts of door jambs and casings should be cut off at least 6 inches above the ground or floor and replaced with cement plinths, which should project one-quarter inch beyond the jambs and casings. Metal strips should be sunk down from the woodwork into the concrete. Wooden thresholds, wainscoting, window sills, subsills, and stools in the basement or ground floor should be removed and placed on concrete (a layer of concrete between the earth and wood) or replaced with concrete.

REPLACING WITH METAL

In basements and cellars steel rails or other structural metal work can sometimes be economically used to replace weakened timbers.

FUMIGATION AND SPRAYING

Fumigation and spraying are of no permanent value against subterranean termites in buildings, since, while they may kill the flying insects and some of those in the wood, others will continue to come up from the ground.

In the case of termites which do not live in the ground, however, but attack wood directly, fumigation with hydrocyanic-acid gas will kill them in the woodwork of buildings, boats, etc. Infested woodwork should be opened up and exposed as much as possible. Furniture should be stored in a tightly closed room and there fumigated. The woodwork of several boats and large hotels in Florida has been

successfully fumigated with hydrocyanic-acid gas according to the recommendations of the Bureau of Entomology.[9] Where the termites had infested several stories of the buildings, the windows were sealed, and after the fumigation was completed the rooms were aired by opening windows with cords from the outside. The usual proportions were employed;[10] that is, 1 ounce (avoirdupois) of sodium cyanide to 1½ fluid ounces of sulphuric acid and 3 fluid ounces of water; but 12 ounces of the cyanide was used per 100 cubic feet of room capacity, instead of the 10 ounces recommended by the Bureau of Entomology, making the gas 20 per cent stronger. This fumigation resulted in the death of the insects within the wood.

In southern Florida, where serious damage is caused to buildings by the West Indian termite *Cryptotermes brevis* Walker, fumigation is recommended just before the winged adults fly (about the middle of June). At that time these insects are in the outer layers of the wood where they are readily accessible, and the fumigation will destroy large numbers of them.

HEAT

Nonsubterranean termites can be killed by the use of heat. In southern Florida these insects were killed in furniture by placing it in an attic with a glass skylight, where the sun's rays caused a very high temperature, from 17 to 24° F. higher than the maximum temperature recorded by the United States Weather Bureau. Temperatures of 110 to 120° F. and over, artificially produced, can likewise be utilized in controlling this class of termites.

INSECTICIDES

Poisons can be used to kill nonsubterranean termites within the wood. Insecticides useful for this purpose are orthodichlorobenzene, or a 10 per cent solution of kerosene emulsion poisoned by dissolving 1 ounce of sodium arsenite in each gallon of water used for diluting stock mixtures of kerosene emulsion or miscible oils. The infested wood is drenched with the chosen insecticide by swabbing with a saturated rag or mop; several treatments may be necessary, and the wood should be placed in quarantine and carefully watched until it is certain that all the termites are dead.

Poisons for subterranean termites are enumerated under the heading "Destruction of breeding places about the building site" (p. 6).

PREVENTING AND REMEDYING INJURY TO LIVING VEGETATION

FRUIT, NUT, SHADE, AND FOREST TREES

Termites cause occasional but serious injury to living trees, shrubs, nursery stock, and grapevines. A wise preventive measure is the removal of all loose wood which may afford them shelter, such as prunings, dead and dying trees and the like, and untreated fence posts and similar material. Cleanliness in orchard and forest man-

[9] See Farmers' Bulletin 699, Hydrocyanic-Acid Gas Against Household Insects. For detailed instructions for fumigating with hydrocyanic-acid gas this publication should be consulted, or application made to the Bureau of Entomology, United States Department of Agriculture, Washington, D. C.

[10] By the State Plant Board of Florida in cooperation with the Bureau of Entomology, United States Department of Agriculture.

agement is important. Since termites render unmerchantable the forest trees which have been killed by insects, fire, or disease, all timber from such trees should be utilized or removed as promptly as possible.

Covering scars and pruned areas.—To prevent infestation, care should be taken that the trees do not become scarred, especially near the base. Scars and all pruned areas should be treated with a mixture of one-fourth creosote and three-fourths coal tar. This mixture should not be allowed to come in contact with the living tissues at the edges of the bark; to protect them a shellac should be applied.

Commerc'al fertilizers.—Soil heavily manured will attract subterranean termites, since they can obtain food from the animal manure; commercial fertilizers should be used in preference in regions where termites are common in the soil.

YOUNG PLANTATIONS OR NURSERY STOCK

Injury to nursery stock will be more serious on recently cleared land, to stock from 1 to 3 years old, and where decaying wood is abundant. Any débris in which the insects breed should be removed. In general the use of recently cleared land should be avoided in planting nursery stock. Earth used in banking should be free from rotten wood. Care should be taken not to allow the roots to dry out before planting, as weakened stock is specially susceptible to attack; particular care should be given grafted stock. In the case of the pecan it is recommended that two or three cereal crops be grown on newly cleared land before the young trees are set out.

Tree surgery.—Properly executed tree surgery [11] sometimes is effective in repairing injury by termites to valuable old fruit and shade trees.

Insecticides.—When valuable trees are infested but not yet dying, subterranean termites can be killed in the soil, if it is moist and not too compact, by breaking it up near the tree and pouring carbon disulphide on the earth at a distance of about a foot from the trunk, then covering the liquid over with earth. The gas from this liquid will penetrate the subterranean galleries of the termites. It is somewhat dangerous to plant life and very large doses should not be used. *Care should be taken in handling this volatile fluid, as the gas or vapor from it is highly inflammable and explosive when mixed with air in certain proportions; no flame should be brought near it, and the fumes should not be inhaled, as they are poisonous.* There are indications that an emulsion of carbon disulphide, which is on the market ready for use, may prove more effective than carbon disulphide alone; as in the case of the disulphide itself, the earth is loosened up and the emulsion poured on, at least a foot from the tree. Carbon tetrachloride,[12] the gas from which is neither explosive nor inflammable, can be similarly used but is apparently not so effective as carbon disulphide. The gases from carbon disulphide

[11] For information on this subject the reader is referred to Farmers' Bulletin 1178, "Tree Surgery," which may be obtained on application to the United States Department of Agriculture.

[12] Carbon tetrachloride is a thin, transparent, colorless, volatile liquid, which forms a gas with a pungent, aromatic odor. Like carbon disulphide it is heavier than air. Although it is only about one-half or one-third as effective as carbon disulphide when used at the same dosage rate, it has the great advantage that its gas is neither explosive nor inflammable; there will be no fire risk attending its use in buildings.

and carbon tetrachloride, being heavier than air, will not readily rise.

If tree trunks or branches are infested, they must be treated with poisonous liquids, such as kerosene emulsion poisoned with sodium arsenite.[13] Orthodichlorobenzene is probably useful in the same way. When treating the infested portions, which are usually in the dead heartwood, these liquids must not be permitted to come in contact with living plant tissue.

VINEYARDS

In vineyards all dead or diseased vines should be removed. All exposed areas left by pruning should be painted with preservative coatings and the prunings should be burned promptly. Near-by stands of tree windbreaks should be carefully cared for and kept free from infestation by termites. Trellis posts should be creosoted.

FIELD AND TRUCK CROPS

Deep fall plowing.—Deep, late, fall plowing will be of value in breaking up the galleries and nests of subterranean termites on ground planted to field or truck crops. Irrigation of the land, where practicable, will be effective; this can be done before planting the crop.

Burning stubble.—Care should be taken not to plow under stubble which will serve as food for termites; it should be burned. The use of commercial fertilizers instead of animal manure is also recommended where subterranean termites are common in the soil.

Insecticides.—Injury to corn in the prairie region of Kansas has resulted from the presence of termites in enormous numbers in the heavily sodded soil, where they feed on the roots of the vegetation. Such soil should be plowed up and treated with insecticides before crops are planted; effective insecticides are sodium arsenite and sodium cyanide. (See p. 6.)

Rotation of crops.—As a result of the frequent stirring of the soil, rotation of crops will aid in preventing termites from injuring them.

FLOWERS AND GREENHOUSE STOCK

Termites injure a great variety of flowers in gardens, as well as many plants grown under glass in greenhouses, where the warm, moist atmosphere maintained throughout the year promotes greatly the activity of the insects. Injury from termites is especially common where the plants are perennial and have woody stalks.

Sources of infestation.—Heavily manured flower beds are a source of infestation to the stems of the flowers, as well as to the woodwork of buildings near by, if suitable protection is lacking. Untreated wooden stakes used as supports of plants often become infested, and in time the insects attack the plants. In greenhouses termites often attack old label sticks, the wooden uprights supporting wooden benches set on or in the ground, and the wooden bench bottoms and plant pots, and later attack the growing plants. The insects come up through the ground and form dirt galleries over the supports, or

[13] In each gallon of the water used for diluting kerosene emulsion or miscible oil, dissolve 1 ounce of sodium arsenite.

burrow up through the wooden bench legs and run galleries the full length of the benches. They enter the soil in the pots through the drainage holes and eat out the main stalk of the root, killing the plant very quickly.

Proper construction of greenhouses.—Proper construction of greenhouses will practically safeguard plants growing in them from all injury by termites. Iron frames and concrete work should, wherever possible, replace bricks or woodwork. In cases of infestation of old greenhouses all wooden uprights supporting wooden plant benches should be sawed off, if set on or in the ground, and rested on stone, bricks, or concrete, above the surface of the ground. Proper repairing, including the removal of all infested wood, will prevent the plants from becoming infested in turn. Where woodwork is necessary the wood should be impregnated with zinc chloride or bichloride of mercury; it can be painted after treatment. Wood impregnated with coal-tar creosote can not be used with safety in greenhouses.

Avoiding stable manure.—In flower gardens, especially those located near the woodwork of buildings, commercial fertilizers should be substituted for stable manure in order to protect not only the buildings but also the growing plants.

Insecticides.—Either carbon disulphide or carbon tetrachloride[14] can be used to kill termites in the soil if it is moist and not compact. Small holes should be made near the infested plants and a small quantity of the liquid chosen poured in and the holes immediately closed tightly with earth. Calcium cyanide[15] has also been found effective, but it should not be placed near living plants; it mixes readily with and enriches the soil and gives off an insecticidal gas which *should not be inhaled, as it is poisonous.*

An effective control may be found in the use of kerosene nicotine oleate or a 5 per cent kerosene emulsion.[16] If the greenhouse benches are infested, but for any reason can not be replaced, they should be soaked thoroughly with this emulsion, as should also the ashes and sand under the pots on the benches. This may be done by removing the potted plants from a section of the bench, spraying that section, and moving the pots on the bench to cover the treated area, thus giving access to another section. Potted heliotropes and geraniums have been treated directly with the 5 per cent kerosene emulsion without injury to the plants, and the white ants in the soil of the pots were all killed. The soil should be wet down before this spray is used. This treatment should be given late in the afternoon and be followed early the next morning with a thorough syringing of the soil with water to wash out the surplus oil. It is important to remove all infested pots from the bench as soon as the infestation is noticed and to destroy the termites with kerosene emulsion.

SUMMARY

Damage by termites or "white ants" is serious to many classes of crude and finished forest products and is occasionally serious to liv-

[14] See footnote 12 (p. 19).

[15] Two ounces of calcium cyanide to 1 square yard of ground is recommended.

[16] Kerosene emulsion is made as follows: Kerosene, 2 gallons; fish-oil soap, one-half pound; water, 1 gallon. Dissolve the soap in hot water and pour in the oil slowly, with constant stirring to emulsify.

Dilution: If 37 gallons of water be added to the above stock emulsion it will give 40 gallons of 5 per cent kerosene emulsion.

ing trees and other plants. These insects are especially injurious to foundation timbers, the woodwork of buildings, and material stored in buildings to which they have gained entrance. Damage to timber in contact with the ground is especially serious in the Southern, Central, and Pacific Coast States and the tropical possessions of the United States.

The woodwork of buildings can be protected from the attack of termites by proper construction and by the use of wood treated with preservatives. These insects can be eliminated where already established in buildings by removing wood in contact with the ground and replacing it with wood chemically treated.

To construct buildings so that they will be white-ant proof, make their foundations, where possible, entirely of stone, brick, or concrete, including stone or metal columns or pillars in the basement to support the floor above; make concrete walls and flooring in basement or cellar, and lay concrete floors on a gravel base. Where stone or concrete foundations are impracticable, use timber impregnated with coal-tar creosote.

Lay basement-window sills and frames over concrete, and do not allow woodwork to come in contact with the ground. Never sink untreated timber in the ground or in moist concrete.

Complete dryness of the foundation and of the basement walls and flooring is an important means of rendering buildings safe from attack. Provide for air spaces between the ground and wooden flooring and lay concrete floors on a gravel base.

In regions where nonsubterranean termites are common (see map, fig. 1) woodwork should be treated with preservatives.

To eliminate termites already established in buildings, examine the foundation timbers and other woodwork in the basement to determine the approximate point of entrance and the extent of damage already accomplished. After removing the damaged wood, drench the ground with insecticides or poisonous solutions. Then replace the damaged timber with rock, brick, concrete, or metal work, or substitute, for the foundation, timbers impregnated with coal-tar creosote.

Since subterranean termites always require access to damp earth, shut off this source of moisture. The insects will then be unable to extend their galleries farther and will perish.

Nonsubterranean termites can be killed in infested wood by fumigation with hydrocyanic-acid gas, by exposure to a temperature above 110° F., or by the use of insecticide solutions.

Injury to living vegetation is occasionally serious, especially in the Southern States, the Southwest, and the Pacific Coast States. It can be prevented by clean cultural methods, deep fall plowing, and the use of insecticides.

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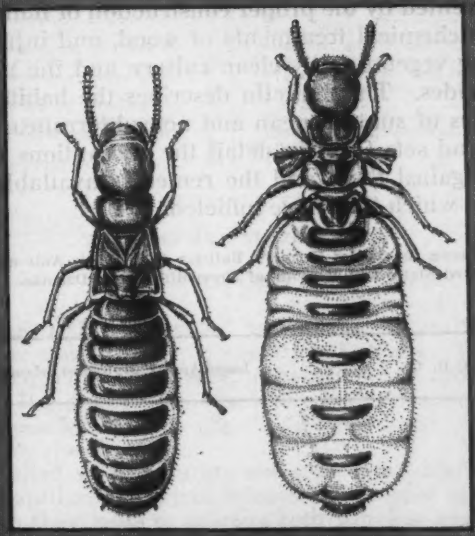
PREVENTING DAMAGE BY TERMITES OR WHITE ANTS



XUM

THROUGHOUT the United States native termites, or white ants, cause serious damage to the foundations and woodwork of buildings and articles in the buildings, as well as to living fruit and other trees, crops, and other vegetation. Such damage can be prevented by the proper construction of buildings and by chemical treatments of wood, and injury to growing vegetation by clean culture and the use of insecticides. This bulletin describes the habits and activities of subterranean and nonsubterranean termites and sets forth in detail the precautions to be taken against them and the remedies available for damage which they have inflicted.

This bulletin supersedes Farmers' Bulletin 1037, White Ants as Pests in the United States and Methods of Preventing Their Damage.

Washington, D. C. Issued April, 1926; revised February, 1927

PREVENTING DAMAGE BY TERMITES OR WHITE ANTS

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TERMITES AND THEIR HABITS

DISTRIBUTION AND FORMS

TERMITES, or "white ants," are destructive native insects of which 42 species occur in the United States. They are distributed throughout the country, although in the southern, southwestern, and Pacific coast regions, where both the subterranean and nonsubterranean kinds occur (fig. 1), they are more numerous and injurious than elsewhere.

These so-called white ants are not true ants, although they are superficially antlike and live in colonies made up of different forms or castes. In these nests or colonies both wingless and winged mature individuals are produced. The brownish or blackish, elongate, slender, antlike, colonizing, sexual adults (fig. 2) with long white wings, unlike the other forms, have functional eyes and their bodies are able to endure full sunlight. These migratory males and females appear normally once a year during a short period. There are three stages in the life of white ants: The egg, the immature form (nymph), and the mature individual (including sterile workers (fig. 12, *b*), soldiers (fig. 12, *a*), and the various fertile reproductive forms).

LOCATION OF COLONIES OR NESTS

The nests of some species of termites[1] are in the earth and in dead and decaying wood. These species are of subterranean habit, timber and trees being attacked by the workers only through the ground. The nests of some other species,[2] however, are excavated in wood and trees by the winged forms, there being no workers and no underground life.

With the clearing of land and the consequent destruction of their natural breeding places in the dead trees, decaying stumps, and logs of the forests, termites become increasingly destructive to the woodwork and contents of buildings (figs. 3–9), telephone poles, fences, or any timber in contact with the ground, as well as to living vegetation, including not only fruit and shade trees, shrubs, and flowers, but also truck (fig. 10) and field crops and, in California,

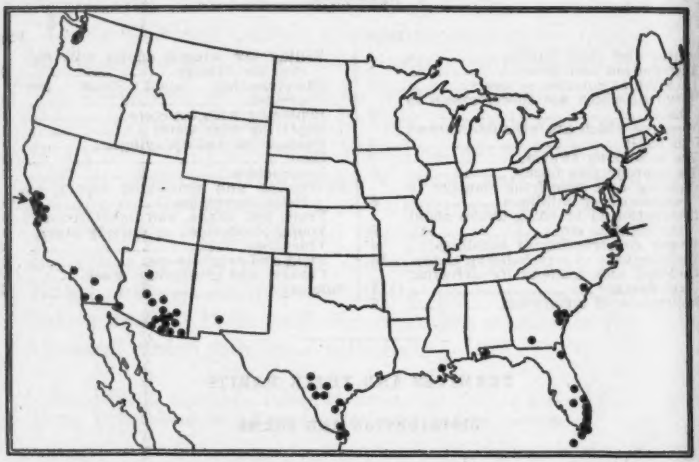

FIG. 1.—Map showing distribution in the United States of nonsubterranean wood-boring termites (Kalotermes and Cryptotermes). The dots indicate localities from which the Bureau of Entomology has records of occurrence or damage. The group of termites of subterranean habits (Reticulitermes, etc.) is much more widely distributed, being represented in practically every part of the United States

grapevines. The principal food of termites is cellulose, which they obtain from either dead or living vegetation.

Termites in the United States are mainly species of subterranean or wood-boring habit and are not so spectacular or common as the mound-making or tree-nesting termites of the Tropics. Very few termites in this country have habits which make them conspicuous, or come above ground into the sunlight, except during the annual colonizing swarm; hence they largely escape notice until they become injurious.

TERMITES WHICH ARE SUBTERRANEAN IN HABIT

Subterranean termites live in forests, building their nests in the wood of standing timber, logs, or stumps, in cleared land, any wood

[1] Genera Reticulitermes Holmgren, Leucotermes Silvestri, Amitermes Silvestri, etc.
[2] Genera Kalotermes Hagen, Neotermes Holmgren, Cryptotermes Banks, etc.

in contact with the ground or, in the plains, in a labyrinth of underground passages in the earth, usually underneath wood or vegetation.

Termites are soft-bodied and always conceal themselves within wood, in the earth, or within their earthlike carton shelter tubes (fig. 11). The grayish-white, soft-bodied, wingless, sterile "workers" (fig. 12, *b*) are in reality the destructive form. These workers make the excavations occupied by the colony and enlarge and extend them as the colony increases. They live underground or within the wood, are blind, and shun the light; as a result they are rarely seen. In burrowing through wood the workers often completely honeycomb it, usually following the grain and eating out the softer, thin-walled, larger-celled spring or new wood. They are able to penetrate the hardest of woods, provided they have access to moisture in the ground. In extending their galleries in wood and vegetation, subterranean species carry moisture with them by means of moist excrement mixed with earth.

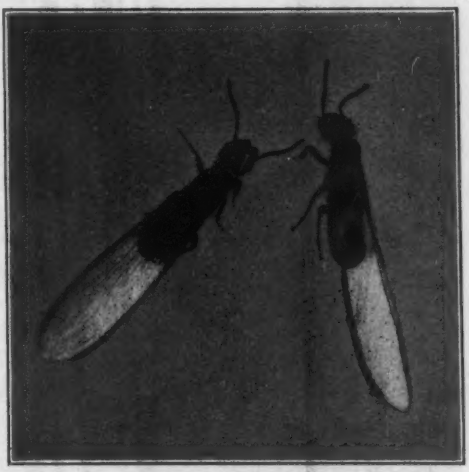

FIG. 2.—Winged sexual adults of an eastern subterranean termite, *Reticulitermes virginicus*. Nearly six times natural size

TERMITES WHICH ARE NONSUBTERRANEAN IN HABIT

The nonsubterranean termites which are injurious attack wood directly; but, instead of following the grain continuously, they excavate through it longitudinal chambers of limited length. The sexual adults, after they have lost their wings, and the young or nymphs, are the destructive forms. Their pellets of excrement (fig. 13) are regularly impressed, and sometimes completely fill or block up the burrows in a compact mass; they are often expelled as dry droppings from the infested wood. These termites are destructive to the woodwork and furniture in buildings (figs. 14, 15), as well as to living trees. Apparently they can exist without the great amount of moisture necessary to the life of termites which are subterranean in habit.

THE COLONIZING SWARM

At certain seasons, usually spring or fall, but varying with the species and the locality, the winged, sexual individuals migrate in large numbers from the parent nests. They then lose their wings and breed new colonies. In the case of the subterranean termites, wood and trees are usually entered indirectly through the ground,

although sometimes these insects enter trees under bark loosened by sunburn, etc., or through scars or borer holes, provided sufficient moisture is present. Nonsubterranean termites enter the wood directly, or, in the case of trees, through wounds or borer holes or under loose bark; moisture is not necessary.

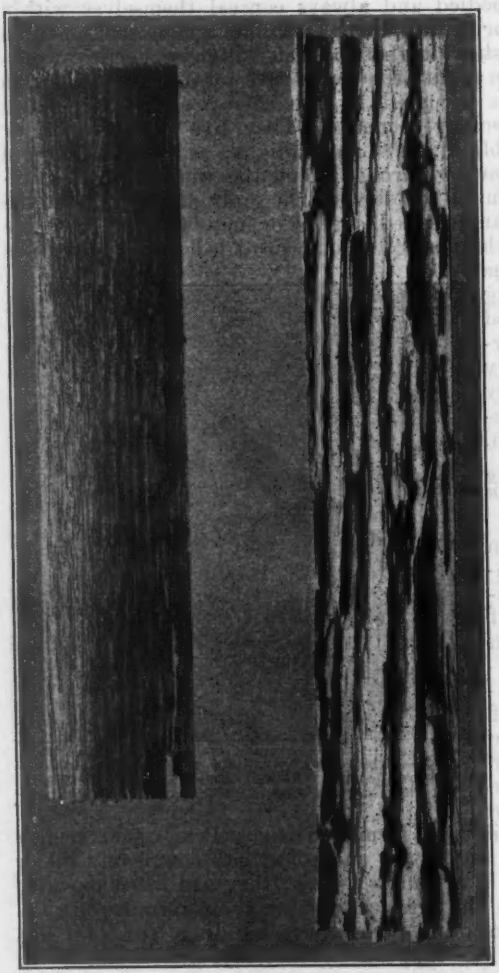

FIG. 3.—Damage to oak flooring by the common eastern subterranean termite *Reticulitermes flavipes*. Note that damage is not apparent on upper surface

In the new quarters eggs are laid, the young develop, and in a few years the colony increases in numbers, and the "workers" are able to feed and care for the reproductive forms—the "king" (title page, left) and "queen" (title page, right)—as well as the soldiers (fig. 12, *a*), which are sterile forms adapted to protect the colony from insect enemies, notably the true ants. In recently formed young colonies the rate of egg laying is slow, but mating is repeated, and, although there is at first a gradual increase, later the increase in the numbers of the broods is rapid. In old colonies there are thousands and tens of thousands of individuals.

Egg laying occurs over a considerable period during the warm months in colonies out of doors. In infested buildings artificially heated, where an even temperature is maintained, the insects are active and may lay eggs every month of the year. The number of eggs laid depends on age.

THE REPRODUCTIVE FORMS

Owing to the increasing number of eggs that develop within her, the queen becomes enlarged, but never loses the power of locomotion. It was once believed that, since the queen mother was the source of the colony life, the termite colony would be exterminated if she were destroyed, but this has been disproved by more recent studies. In addition to the forms that have shed their wings, several different types of reproductive forms occur—forms with wing pads (the undeveloped wings of the nymphs) and wingless reproductive adults. The winged forms, however, are the normal type and occur as a single pair, whereas there may be hundreds of the other forms heading colonies. The reproductive forms with wing pads and the wholly wingless type usually have little color to the body, and the eyes are small. These forms rarely come above ground or leave the burrows in wood.

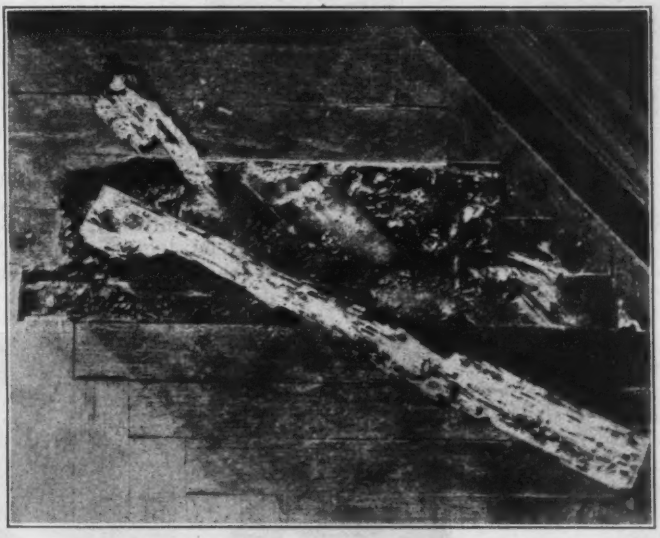

FIG. 4.—Quartered-oak flooring damaged by the subterranean termite *Reticulitermes flavipes* in an infested building, Washington, D. C., 1915

The location of the queens in the colony depends upon the season of the year. During periods of intense heat or drought in the plains or in arid or prairie regions the subterranean termites burrow deeply below ground or to a less depth under stones, cow chips, etc. During winter in the colder climates they burrow below the frost line.

Whole colonies of subterranean termites migrate when conditions become unfavorable. The nonsubterranean termites, on the other hand, are not able to leave the wood in which they have excavated their nests.

PREVENTING AND REMEDYING DAMAGE TO WOODWORK OF BUILDINGS

DESTRUCTION OF BREEDING PLACES ABOUT THE BUILDING SITE

If buildings are to be constructed on recently cleared woodland, decaying logs and stumps should be removed from the soil in the vicinity and burned. If, because of the presence of decaying wood and humus, the subterranean termites are numerous in the earth, the soil should be deeply plowed or otherwise broken up and treated with chemicals to kill the insects. Effective poisons for this purpose are sodium cyanide;[3] a 10 per cent solution of sodium arsenite; kerosene oil; 1 part coal-tar creosote and 3 parts kerosene oil (this mixture should be strained through burlap before use); carbon-disulphide emulsion, which is on the market ready for use; orthodichlorobenzene; lye; or other contact poisons or gases. Live steam forced into the soil will serve the same purpose as the gases. Decaying fence posts, sidewalks, etc., should be removed and replaced with treated wood, concrete, stone, or other resistant substances; such decaying material would facilitate the formation or perpetuation of the termite colonies.

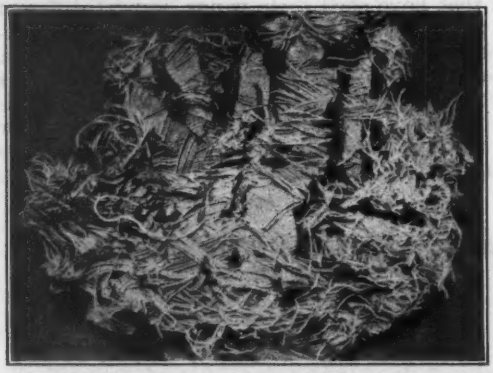

FIG. 5.—Tube of coarse yarn from bale of cotton on floor of building infested by subterranean termites, Greenville, S. C.

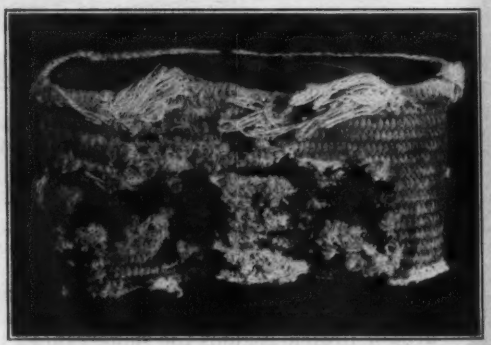

FIG. 6.—Cotton jacket of rubber-lined fire hose from infested building in Missouri, damaged by subterranean termites (*Reticulitermes* sp.)

PROPER CONSTRUCTION OF BUILDINGS

Termites will infest not only old buildings but also improperly constructed new buildings, and these are often badly infested. It is not the age of the building but the manner in which it has been constructed that renders it liable to attack.

Insulation.—Complete insulation from the ground of all untreated woodwork of buildings is the only effective permanent remedy

[3] For each acre to be treated, dissolve 160 pounds of granular sodium cyanide in 12,000 gallons of water.

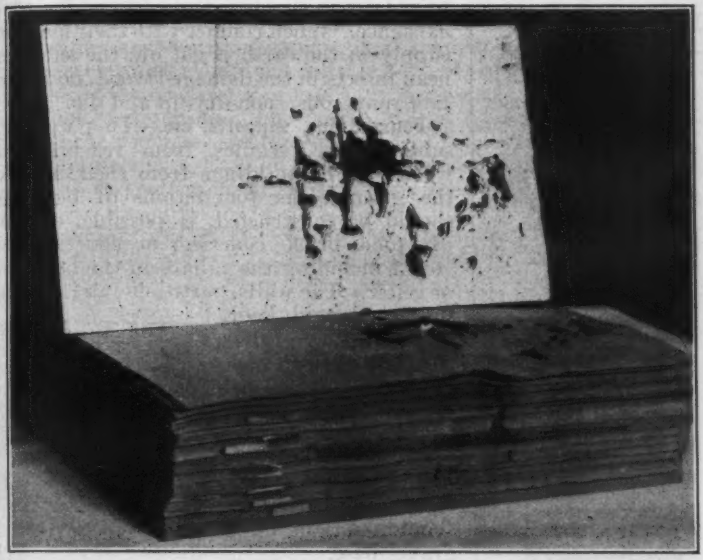

FIG. 7.—Revenue stamps damaged by the subterranean termite *Reticulitermes flavipes* on infested flooring in the Bureau of Engraving and Printing, Washington, D. C., 1921

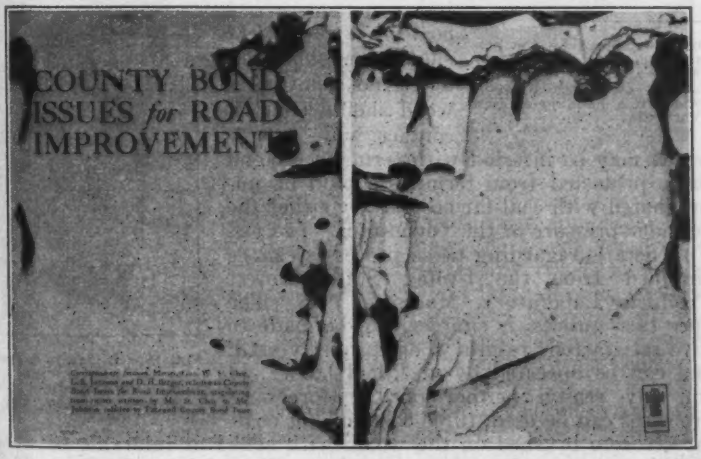

FIG. 8.—Correspondence and advertisement regarding issue of county bonds; damaged by subterranean termites infesting the building in Virginia in which they were stored

against attack by subterranean termites, and the only relief from their presence. These insects must maintain contact with the ground to obtain the moisture necessary for their existence. When contact with their moisture supply in the earth is cut off, the subterranean insects in the damaged wood, no matter how numerous, soon dry up and die.

FIG. 9.—Damage by the subterranean termite *Reticulitermes flavipes* to shoe stored on infested woodwork in a building in New York City

Foundations, supports, etc.—To prevent subterranean termites from reaching the woodwork of buildings from their nests in the ground, the foundations of buildings should be constructed, if possible, entirely of stone, brick, concrete, or concrete and steel,[4] including the pillars in the basement or cellar. The walls, partitions, and flooring in the ground floor, basement, or cellar should also be of concrete. Wooden flooring can be laid over this concrete floor if desired. If the flooring is to be of concrete, the concrete should be laid on a gravel base.

FIG. 10.—Injury to carrots by the subterranean termite *Reticulitermes claripennis*, at Dallas, Tex.

In buildings where stone, brick, or concrete foundations are impracticable, timber impregnated with coal-tar creosote should be employed, and no untreated wood should come in contact with ground which may be infested with termites. Wood to be protected from termites should be impregnated with coal-tar creosote by either the cylinder-pressure or the "open-tank" process. Full details regarding these processes can be obtained from the United States Forest Products Laboratory, Madison, Wis. The open-tank process is simpler, can be made to give satisfactory results where properly used, and can be operated by unskilled labor. If for any reason neither of the foregoing processes can be used, three coats of hot coal-tar creosote brushed on the wood, with sufficient intervals between brushings to permit each coat to dry, will be fairly effective. This

[4] In the Southern States, especially in the subtropics, the more valuable permanent buildings should be constructed entirely of steel and concrete.

method, however, is not generally recommended, since it will preserve the wood for only a few years.

The supports of porches or steps should never be laid directly on the ground, but should rest on rock or concrete. Window sills and frames in the basement or cellar should be laid over concrete and the woodwork should not come in contact with the ground. The supports of the woodwork of coal bins in basements or cellars should not be set in the ground, but should rest on concrete, not extending through the concrete into the soil.

Concrete flooring.—Even in permanent stone or concrete and steel buildings the concrete flooring is often constructed improperly.

FIG. 11.—Carton, earthlike, shelter tubes constructed by the eastern subterranean termite *Reticulitermes flavipes* over brick wall in dark, heated, damp basement; these tubes are used in passing over impenetrable substances. Inset, near view of tubes to show texture

Usually the base of the concrete floor is a loose combination of coarse gravel or cinders and cement grout. This very rough conglomerate, even if several inches thick, has many cracks and large holes running through it. Over this is laid a layer of solid concrete about 2 or 3 inches thick, of fine texture, in which untreated wooden sleepers are laid while it is still moist. These sleepers nearly or quite reach the coarse, open conglomerate in contact with the earth, and to them is nailed the wooden flooring. (Fig. 17, A.)

It will be seen that this is faulty construction. Termites have free access from the earth, in which they have galleries, through the porous conglomerate, to the untreated beams and flooring. *There should be a layer of solid concrete at least 1 inch thick between the grout and the wood.* (Fig. 17, B.)

Among the commonest means of infestation are wooden sleepers or stringers laid in concrete while the latter is still soft, or placed before the concrete has been poured in. Termites enter through these wooden beams. Other common means of infestation are supports of coal bins extending through concrete and through the disintegrated lime mortar of brick walls.

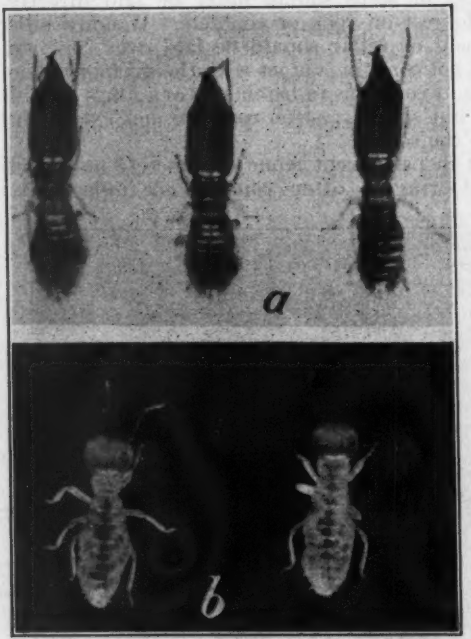

FIG. 12.—Mature soldiers (*a*) and mature workers (*b*) of the eastern subterranean termite *Reticulitermes flavipes*. Slightly more than six times natural size

Termite shields, guards, or metal caps.—The most injurious termites in this country are subterranean in habit and require constant access to the earth in order to attack wood which is either in contact with the earth or which they reach through covered, earthlike shelter tubes constructed over the face of stone, concrete, or brick foundations. In consequence they can be kept out of buildings by means of metal barriers. By simply inserting a sheet of galvanized iron or "termite shield" into the masonry and turning the projecting edges downward at an angle, communication of termites with the earth, where they obtain moisture, can be cut off. In less pretentious frame buildings, metal caps are placed over the tops of construction stone piling or pillars, or wooden supports.

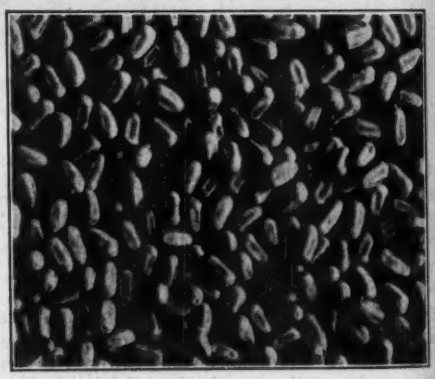

FIG. 13.—Impressed pellets of excrement of nonsubterranean termites (*Kalotermes* sp.), which drop from infested wood. Greatly enlarged

This is a similar method to that used in rat-proofing corn cribs. It is effective and practicable where untreated timber is placed over masonry foundations.

Again, in the case of stone and steel buildings, the steel or stone pillars or piping extending down through the concrete floor to foundations in the earth often make infestation possible, owing to the fact that the concrete floor does not fit tightly about them. Overlapping strips of metal extending horizontally several inches from the pillars or pipes should be imbedded in the concrete floor in order to obtain a tight joint (fig. 17, B); or liquid (adhesive) asphalt should be poured in to plug up the crevice or frame.

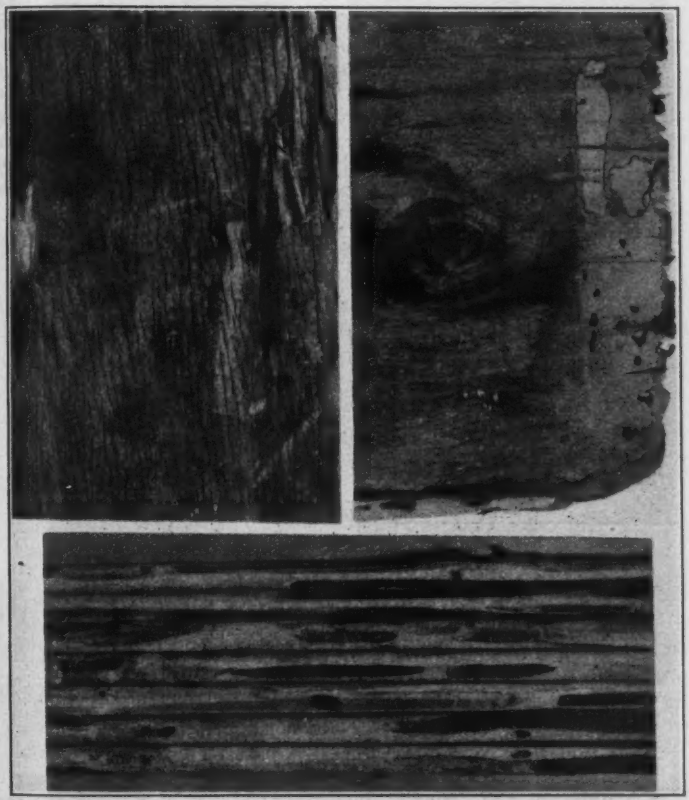

FIG. 14.—Bottom of bureau drawer damaged by the nonsubterranean wood-boring termite *Cryptotermes brevis*, which occurs at Key West, Miami, and Palm Beach, Fla.

Avoiding dampness.—Complete dryness of foundation timbers and basement walls and flooring is an important aid in rendering buildings safe from attack by termites. Dampness, warmth, and darkness attract these insects. A deep air space should be left between the ground and wooden flooring, unless, as in factories, heavy trucking is to be used over the floor, in which case this is impracticable. An air space should be left between the concrete floor and the wooden floor laid over it. Concrete floors should be laid on a gravel

base, which will prevent dampness and cracking. The points of juncture between concrete walls and wooden flooring should be filled in by rounding off the concrete at these places, since cracks often occur where the wall and floor join at right angles. (Fig. 17,

FIG. 15.—Furniture damaged by the nonsubterranean, wood-boring termite *Cryptotermes brevis*, Key West, Fla.

B.) Termites often come up through cracks between walls and flooring.

By mixing a heavy mineral residual oil with Portland cement, a material is formed almost perfectly nonabsorbent of water and therefore excellent for use in damp-proof construction. Where the

various patent or noiseless floorings are used on the ground floor they should always be laid over a concrete base, especially if they contain wood fiber as a constituent.

In no case should untreated beams be completely surrounded with mortar or brick; there should be a space around them sufficient to permit air circulation. Beams should not be set in earth or in moist concrete, but on rock or dry concrete, or in grooves in the latter.

Bungalows or frame buildings which have no cellar should be raised from the ground on stone, concrete, or brick foundations to a height which will allow light and air to penetrate beneath.

Lime mortar.—In brick walls, where lime mortar is used, this sometimes disintegrates after a few years and termites penetrate through the spaces thus left between the bricks, especially where the brickwork is below the ground level. (Fig. 16.) Such walls should be faced with Portland cement 1 inch thick, especially if untreated wood is to come in contact with the bricks.

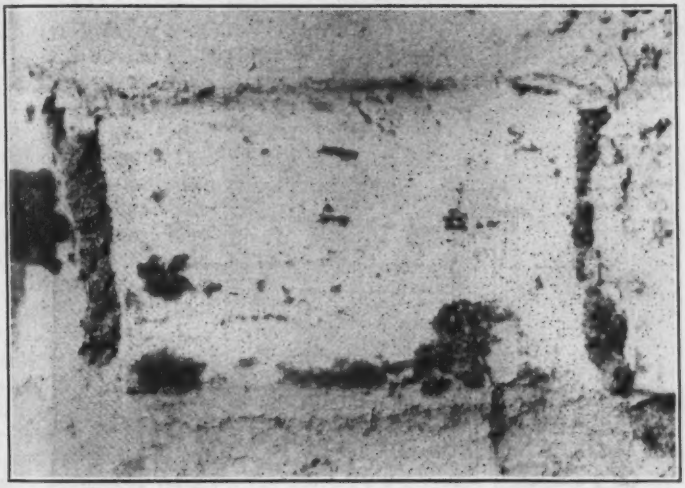

FIG. 16.—Interior view of portion of whitewashed brick foundation wall of building, below ground level, showing shelter tubes of our common subterranean termite (*Reticulitermes* sp.) penetrating the disintegrated lime mortar. These termites came through the earth banked up against the exterior wall. To remedy this condition the exterior wall will have to be faced with concrete for some distance below the ground level

Use of chemically treated wood for interior woodwork, furniture, etc.—In the Southern States, especially in the subtropics, in the more valuable permanent buildings the interior woodwork, furniture, etc., should be impregnated with preservatives, since nonsubterranean termites that attack wood directly are common in those regions. Zinc chloride, bichloride of mercury,[5] sodium fluoride, and chlorinated naphthalene[6] are effective preservatives.

[5] The extremely poisonous character of mercuric chloride renders its use dangerous. It is slowly volatile, and there is a possibility that it will be given off continuously in small quantities from the treated wood. However, it has been extensively used in Germany and apparently without serious consequences.

[6] This preservative is usually referred to as trichlornaphthalene and, as compared with other chemicals, it is really comparable to a technical product having naphthalene, monochloronaphthalene, dichlornaphthalene, and probably some of the higher chlorinations as impurities. Its melting point ranges between 190 and 210° F.—the specification under which it is sold.

Wood-pulp products, such as the various wood-fiber processed or composition boards, or cane-fiber boards, for interior finish and substitutes for lath (fig. 18), or for exterior use, can be protected from attack by termites by adding certain poisons, such as crude carbolic acid, to the pulp or laminated boards in the course of manu-

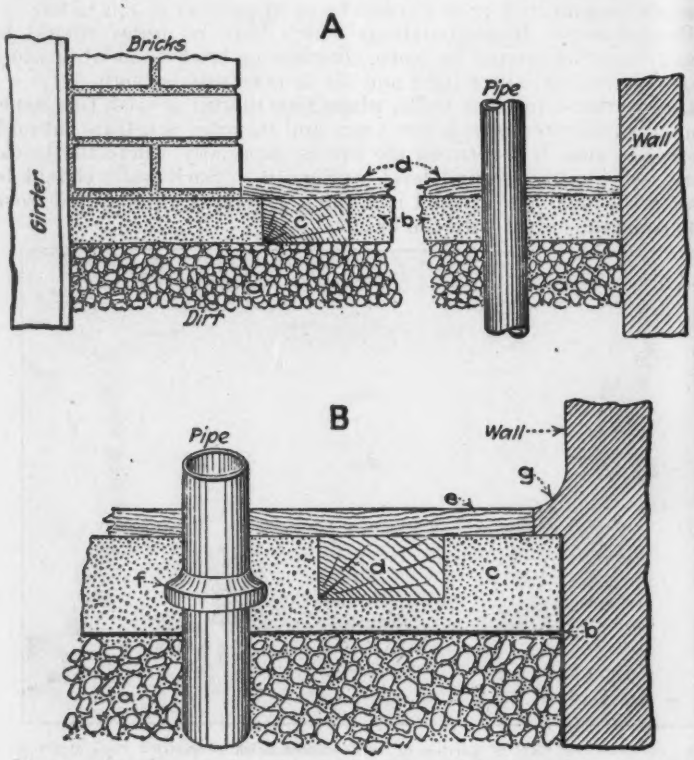

FIG. 17.—A, Improperly constructed concrete flooring: *a*, Gravel or cinders loosely cemented with coarse concrete, 3 inches thick, but with many crevices and holes; *b*, solid, dense concrete, 2 inches thick; *c*, 2 by 4 inch untreated wood sleeper set in moist concrete over the grout; *d*, ⅞-inch pine flooring nailed to sleepers. B, Properly constructed concrete flooring: *a*, Gravel or cinders loosely cemented with coarse concrete, but with many crevices and holes; *b*, asphalt waterproofing ⅛ inch thick; *c*, dense concrete, 3 inches thick; *d*, 2 by 4 inch treated wood sleeper set in a groove in concrete which insulates it from termites in the earth; *e*, ⅞-inch flooring nailed on sleepers; *f*, metal collar around pipe which runs down through the concrete (this collar should be soldered to the pipe and embedded in the concrete); *g*, shoulder of concrete at point of wall and concrete floor to avoid a right-angle connection and consequent cracking

facture. Available poisons for this purpose are crude carbolic acid at the rate of 1 gallon to 1,000 square feet; bichloride of mercury at the rate of 49 ounces per 1,000 square feet; or copper sulphate at the rate of 113 ounces per 1,000 square feet.

MODIFICATIONS OF CITY BUILDING CODES

One of the simplest and most effective means of prevention of attack would be to modify the building regulations or codes of various cities so as to include a few simple rules to protect houses from damage by termites. As the principal object in view is to keep all untreated wood from contact with the ground, where the termites live and from which they get their moisture, the regulations should stipulate that no floors, sills, beams, clapboard, etc., of untreated wood may be laid on or in the earth and that untreated beams may not be laid in concrete without at least 1 inch of concrete underneath and separating it from the earth; that in foundations or in cellar walls in contact with the earth a special grade of hard mortar should be used, since lime mortar[1] after some years' service disintegrates; that all brickwork extending below the surface of the ground shall be faced and capped with concrete at least 1 inch thick; and, where nonsubterranean as well as subterranean termites occur, that only woodwork impregnated with preservatives be used for exterior and interior construction, unless it is impracticable to obtain such treated wood.

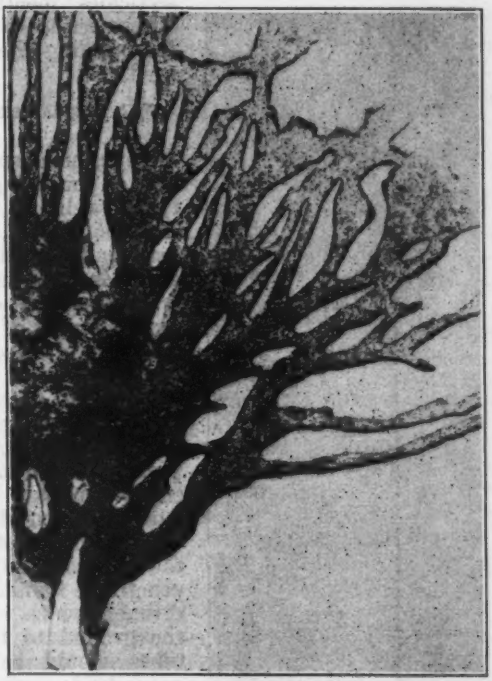

FIG. 18.—Pressed wood-pulp tile mined by subterranean termites infesting the building, Biloxi, Miss.

LOCATING AND TEMPORARILY ARRESTING THE DAMAGE

Although it may be difficult to eliminate termites and stop further damage by them, when once these insects have become established in the woodwork of a building, the approximate point of entrance should be sought at once by careful examination of all woodwork in contact

[1] The Bureau of Standards of the United States Department of Commerce recommends a mortar composed of 1 part Portland cement to 3 parts of sand graded from fine to coarse, with no grains larger than will pass through the No. 10 sieve, to which may be added 10 per cent by weight of the cement of some workability agent, such as hydrated lime, for use in locations where termites abound. Such a mortar, it is believed, will have the desirable properties of both cement and lime mortars and, furthermore, will contain a sufficient quantity of cement to prevent the penetration of it by the termites. (See fig. 16.)

with the ground. To do this, it may be necessary to tear up the foundations, flooring, and some other woodwork. The foundation timbers and interior woodwork found damaged should be removed, and the ground where they were set should be broken up and drenched with some liquid which will kill or at least temporarily prevent the further activity of termites at that point. Any of the insecticides [8] mentioned under the heading "Destruction of breeding places about the building site" (p. 6) will meet the need.

FIG. 19.—Entrance holes of sexual, colonizing adults of a nonsubterranean termite (*Kalotermes hubbardi*) in wood of dead cottonwood tree in Arizona

INDICATIONS OF INFESTATION

The annual emergence of large numbers of the flying termites is an indication as well as a warning that the woodwork is infested, and the point of emergence indicates the approximate location of the infested timbers. Even if the insects are not observed "swarming," large numbers of the dead winged adults or of the discarded wings usually will be found near by. Frass and earth thrown out of crevices through which the insects emerge are also evidences of their presence. Another warning is the presence of branching shelter tubes of small diameter, made of earth mixed with finely powdered wood, on foundation timbers or other woodwork, or over the surface of stone, brick, or other impenetrable foundation material (fig. 11), through which the insects travel from the ground to the woodwork. These tubes should be broken off and the ground where they originate broken up and drenched with one of the liquids named in the paragraph under the heading, "Destruction of breeding places about the building site" (p. 6).

In the case of the nonsubterranean termites, which infest wood directly, evidences that they are damaging wood are the impressed pellets of excrement (fig. 13) which are expelled from the wood. Other evidences are the holes, similar in size to BB shot, where the insects entered the wood. (Fig. 19.)

KILLING THE WINGED ADULTS WILL NOT STOP THE DAMAGE

When efforts are made to prevent further damage by termites in buildings, it should be realized that the numbers of these insects may be constantly recruited from some undiscovered, outside, central colony. The destruction of the winged colonizing adults with house-

[8] If sodium cyanide is used, a strong solution, 1 ounce to a gallon of water, is desirable.

hold ammonia, etc., at the time of emergence, although beneficial in preventing the establishment of new colonies, will not eradicate the insects infesting the woodwork. The most destructive forms are the white, wingless workers, which remain within the wood.

DISCONNECTING WOOD FROM THE GROUND

Subterranean termites infesting beams or other wood will die out if the wood is disconnected from the ground. Knowledge of this fact will save time and expense, especially in the case of old frame buildings, where extensive repairs would be unwarranted. Disconnecting untreated foundation timbers from contact with the soil will also cause the death of subterranean termites in the other woodwork, furniture, and stored material in the building, even if they have penetrated to the second or third floors. These timbers need not be removed or replaced unless seriously weakened structurally. However, if the wood is kept moist by some other means, such as water leakage, the termites will continue to work and thrive. This applies especially to damp corners of basements near outside water pipes, bathrooms, kitchens, and the like.

Wooden floors laid directly on the ground or on stringers on the ground, or set in concrete, should be removed. There should be a layer of concrete between the earth and the wooden floor (fig. 17, B). Wooden baseboards should be removed.

REPLACING WITH CONCRETE

Concrete floors and concrete baseboards should be substituted for wood. Untreated beams penetrating through concrete floors into the earth and the lower parts of door jambs and casings should be cut off at least 6 inches above the ground or floor and replaced with cement plinths, which should project one-quarter inch beyond the jambs and casings. Metal strips should be sunk down from the woodwork into the concrete. Wooden thresholds, wainscoting, window sills, subsills, and stools in the basement or ground floor should be removed and placed on concrete (a layer of concrete between the earth and wood) or replaced with concrete.

REPLACING WITH METAL

In basements and cellars steel rails or other structural metal work can sometimes be economically used to replace weakened timbers.

FUMIGATION AND SPRAYING

Fumigation and spraying are of no permanent value against subterranean termites in buildings, since, while they may kill the flying insects and some of those in the wood, others will continue to come up from the ground.

In the case of termites which do not live in the ground, however, but attack wood directly, fumigation with hydrocyanic-acid gas will kill them in the woodwork of buildings, boats, etc. Infested woodwork should be opened up and exposed as much as possible. Furniture should be stored in a tightly closed room and there fumigated. The woodwork of several boats and large hotels in Florida has been

successfully fumigated with hydrocyanic-acid gas according to the recommendations of the Bureau of Entomology.[9] Where the termites had infested several stories of the buildings, the windows were sealed, and after the fumigation was completed the rooms were aired by opening windows with cords from the outside. The usual proportions were employed;[10] that is, 1 ounce (avoirdupois) of sodium cyanide to 1½ fluid ounces of sulphuric acid and 3 fluid ounces of water; but 12 ounces of the cyanide was used per 1,000 cubic feet of room capacity, instead of the 10 ounces recommended by the Bureau of Entomology, making the gas 20 per cent stronger. This fumigation resulted in the death of the insects within the wood.

In southern Florida, where serious damage is caused to buildings by the West Indian termite *Cryptotermes brevis* Walker, fumigation is recommended just before the winged adults fly (about the middle of June). At that time these insects are in the outer layers of the wood where they are readily accessible, and the fumigation will destroy large numbers of them.

HEAT

Nonsubterranean termites can be killed by the use of heat. In southern Florida these insects were killed in furniture by placing it in an attic with a glass skylight, where the sun's rays caused a very high temperature, from 17 to 24° F. higher than the maximum temperature recorded by the United States Weather Bureau. Temperatures of 110 to 120° F. and over, artificially produced, can likewise be utilized in controlling this class of termites.

INSECTICIDES

Poisons can be used to kill nonsubterranean termites within the wood. Insecticides useful for this purpose are orthodichlorobenzene, or a 10 per cent solution of kerosene emulsion poisoned by dissolving 1 ounce of sodium arsenite in each gallon of water used for diluting stock mixtures of kerosene emulsion or miscible oils. The infested wood is drenched with the chosen insecticide by swabbing with a saturated rag or mop; several treatments may be necessary, and the wood should be placed in quarantine and carefully watched until it is certain that all the termites are dead.

Poisons for subterranean termites are enumerated under the heading "Destruction of breeding places about the building site" (p. 6).

PREVENTING AND REMEDYING INJURY TO LIVING VEGETATION

FRUIT, NUT, SHADE, AND FOREST TREES

Termites cause occasional but serious injury to living trees, shrubs, nursery stock, and grapevines. A wise preventive measure is the removal of all loose wood which may afford them shelter, such as prunings, dead and dying trees and the like, and untreated fence posts and similar material. Cleanliness in orchard and forest man-

[9] See Farmers' Bulletin 699, Hydrocyanic-Acid Gas Against Household Insects. For detailed instructions for fumigating with hydrocyanic-acid gas this publication should be consulted, or application made to the Bureau of Entomology, United States Department of Agriculture, Washington, D. C.

[10] By the State Plant Board of Florida in cooperation with the Bureau of Entomology, United States Department of Agriculture.

agement is important. Since termites render unmerchantable the forest trees which have been killed by insects, fire, or disease, all timber from such trees should be utilized or removed as promptly as possible.

Covering scars and pruned areas.—To prevent infestation, care should be taken that the trees do not become scarred, especially near the base. Scars and all pruned areas should be treated with a mixture of one-fourth creosote and three-fourths coal tar. This mixture should not be allowed to come in contact with the living tissues at the edges of the bark; to protect them a shellac should be applied.

Commercial fertilizers.—Soil heavily manured will attract subterranean termites, since they can obtain food from the animal manure; commercial fertilizers should be used in preference in regions where termites are common in the soil.

YOUNG PLANTATIONS OR NURSERY STOCK

Injury to nursery stock will be more serious on recently cleared land, to stock from 1 to 3 years old, and where decaying wood is abundant. Any débris in which the insects breed should be removed. In general the use of recently cleared land should be avoided in planting nursery stock. Earth used in banking should be free from rotten wood. Care should be taken not to allow the roots to dry out before planting, as weakened stock is specially susceptible to attack; particular care should be given grafted stock. In the case of the pecan it is recommended that two or three cereal crops be grown on newly cleared land before the young trees are set out.

Tree surgery.—Properly executed tree surgery [11] sometimes is effective in repairing injury by termites to valuable old fruit and shade trees.

Insecticides.—When valuable trees are infested but not yet dying, subterranean termites can be killed in the soil, if it is moist and not too compact, by breaking it up near the tree and pouring carbon disulphide on the earth at a distance of about a foot from the trunk, then covering the liquid over with earth. The gas from this liquid will penetrate the subterranean galleries of the termites. It is somewhat dangerous to plant life and very large doses should not be used. *Care should be taken in handling this volatile fluid, as the gas or vapor from it is highly inflammable and explosive when mixed with air in certain proportions; no flame should be brought near it, and the fumes should not be inhaled, as they are poisonous.* There are indications that an emulsion of carbon disulphide, which is on the market ready for use, may prove more effective than carbon disulphide alone; as in the case of the disulphide itself, the earth is loosened up and the emulsion poured on, at least a foot from the tree. Carbon tetrachloride,[12] the gas from which is neither explosive nor inflammable, can be similarly used but is apparently not so effective as carbon disulphide. The gases from carbon disulphide

[11] For information on this subject the reader is referred to Farmers' Bulletin 1178, "Tree Surgery," which may be obtained on application to the United States Department of Agriculture.

[12] Carbon tetrachloride is a thin, transparent, colorless, volatile liquid, which forms a gas with a pungent, aromatic odor. Like carbon disulphide it is heavier than air. Although it is only about one-half or one-third as effective as carbon disulphide when used at the same dosage rate, it has the great advantage that its gas is neither explosive nor inflammable; there will be no fire risk attending its use in buildings.

and carbon tetrachloride, being heavier than air, will not readily rise.

If tree trunks or branches are infested, they must be treated with poisonous liquids, such as kerosene emulsion poisoned with sodium arsenite.[18] Orthodichlorobenzene is probably useful in the same way. When treating the infested portions, which are usually in the dead heartwood, these liquids must not be permitted to come in contact with living plant tissue.

VINEYARDS

In vineyards all dead or diseased vines should be removed. All exposed areas left by pruning should be painted with preservative coatings and the prunings should be burned promptly. Near-by stands of tree windbreaks should be carefully cared for and kept free from infestation by termites. Trellis posts should be creosoted.

FIELD AND TRUCK CROPS

Deep fall plowing.—Deep, late, fall plowing will be of value in breaking up the galleries and nests of subterranean termites on ground planted to field or truck crops. Irrigation of the land, where practicable, will be effective; this can be done before planting the crop.

Burning stubble.—Care should be taken not to plow under stubble which will serve as food for termites; it should be burned. The use of commercial fertilizers instead of animal manure is also recommended where subterranean termites are common in the soil.

Insecticides.—Injury to corn in the prairie region of Kansas has resulted from the presence of termites in enormous numbers in the heavily sodded soil, where they feed on the roots of the vegetation. Such soil should be plowed up and treated with insecticides before crops are planted; effective insecticides are sodium arsenite and sodium cyanide. (See p. 6.)

Rotation of crops.—As a result of the frequent stirring of the soil, rotation of crops will aid in preventing termites from injuring them.

FLOWERS AND GREENHOUSE STOCK

Termites injure a great variety of flowers in gardens, as well as many plants grown under glass in greenhouses, where the warm, moist atmosphere maintained throughout the year promotes greatly the activity of the insects. Injury from termites is especially common where the plants are perennial and have woody stalks.

Sources of infestation.—Heavily manured flower beds are a source of infestation to the stems of the flowers, as well as to the woodwork of buildings near by, if suitable protection is lacking. Untreated wooden stakes used as supports of plants often become infested, and in time the insects attack the plants. In greenhouses termites often attack old label sticks, the wooden uprights supporting wooden benches set on or in the ground, and the wooden bench bottoms and plant pots, and later attack the growing plants. The insects come up through the ground and form dirt galleries over the supports, or

[18] In each gallon of the water used for diluting kerosene emulsion or miscible oil, dissolve 1 ounce of sodium arsenite.

burrow up through the wooden bench legs and run galleries the full length of the benches. They enter the soil in the pots through the drainage holes and eat out the main stalk of the root, killing the plant very quickly.

Proper construction of greenhouses.—Proper construction of greenhouses will practically safeguard plants growing in them from all injury by termites. Iron frames and concrete work should, wherever possible, replace bricks or woodwork. In cases of infestation of old greenhouses all wooden uprights supporting wooden plant benches should be sawed off, if set on or in the ground, and rested on stone, bricks, or concrete, above the surface of the ground. Proper repairing, including the removal of all infested wood, will prevent the plants from becoming infested in turn. Where woodwork is necessary the wood should be impregnated with zinc chloride or bichloride of mercury; it can be painted after treatment. Wood impregnated with coal-tar creosote can not be used with safety in greenhouses.

Avoiding stable manure.—In flower gardens, especially those located near the woodwork of buildings, commercial fertilizers should be substituted for stable manure in order to protect not only the buildings but also the growing plants.

Insecticides.—Either carbon disulphide or carbon tetrachloride[14] can be used to kill termites in the soil if it is moist and not compact. Small holes should be made near the infested plants and a small quantity of the liquid chosen poured in and the holes immediately closed tightly with earth. Calcium cyanide[15] has also been found effective, but it should not be placed near living plants; it mixes readily with and enriches the soil and gives off an insecticidal gas which *should not be inhaled, as it is poisonous.*

An effective control may be found in the use of kerosene nicotine oleate or a 5 per cent kerosene emulsion.[16] If the greenhouse benches are infested, but for any reason can not be replaced, they should be soaked thoroughly with this emulsion, as should also the ashes and sand under the pots on the benches. This may be done by removing the potted plants from a section of the bench, spraying that section, and moving the pots on the bench to cover the treated area, thus giving access to another section. Potted heliotropes and geraniums have been treated directly with the 5 per cent kerosene emulsion without injury to the plants, and the white ants in the soil of the pots were all killed. The soil should be wet down before this spray is used. This treatment should be given late in the afternoon and be followed early the next morning with a thorough syringing of the soil with water to wash out the surplus oil. It is important to remove all infested pots from the bench as soon as the infestation is noticed and to destroy the termites with kerosene emulsion.

SUMMARY

Damage by termites or "white ants" is serious to many classes of crude and finished forest products and is occasionally serious to liv-

[14] See footnote 12 (p. 19).

[15] Two ounces of calcium cyanide to 1 square yard of ground is recommended.

[16] Kerosene emulsion is made as follows: Kerosene, 2 gallons; fish-oil soap, one-half pound; water, 1 gallon. Dissolve the soap in hot water and pour in the oil slowly, with constant stirring to emulsify.

Dilution: If 37 gallons of water be added to the above stock emulsion it will give 40 gallons of 5 per cent kerosene emulsion.

ing trees and other plants. These insects are especially injurious to foundation timbers, the woodwork of buildings, and material stored in buildings to which they have gained entrance. Damage to timber in contact with the ground is especially serious in the Southern, Central, and Pacific Coast States and the tropical possessions of the United States.

The woodwork of buildings can be protected from the attack of termites by proper construction and by the use of wood treated with preservatives. These insects can be eliminated where already established in buildings by removing wood in contact with the ground and replacing it with wood chemically treated.

To construct buildings so that they will be white-ant proof, make their foundations, where possible, entirely of stone, brick, or concrete, including stone or metal columns or pillars in the basement to support the floor above; make concrete walls and flooring in basement or cellar, and lay concrete floors on a gravel base. Where stone or concrete foundations are impracticable, use timber impregnated with coal-tar creosote.

Lay basement-window sills and frames over concrete, and do not allow woodwork to come in contact with the ground. Never sink untreated timber in the ground or in moist concrete.

Complete dryness of the foundation and of the basement walls and flooring is an important means of rendering buildings safe from attack. Provide for air spaces between the ground and wooden flooring and lay concrete floors on a gravel base.

In regions where nonsubterranean termites are common (see map, fig. 1) woodwork should be treated with preservatives.

To eliminate termites already established in buildings, examine the foundation timbers and other woodwork in the basement to determine the approximate point of entrance and the extent of damage already accomplished. After removing the damaged wood, drench the ground with insecticides or poisonous solutions. Then replace the damaged timber with rock, brick, concrete, or metal work, or substitute, for the foundation, timbers impregnated with coal-tar creosote.

Since subterranean termites always require access to damp earth, shut off this source of moisture. The insects will then be unable to extend their galleries farther and will perish.

Nonsubterranean termites can be killed in infested wood by fumigation with hydrocyanic-acid gas, by exposure to a temperature above 110° F., or by the use of insecticide solutions.

Injury to living vegetation is occasionally serious, especially in the Southern States, the Southwest, and the Pacific Coast States. It can be prevented by clean cultural methods, deep fall plowing, and the use of insecticides.

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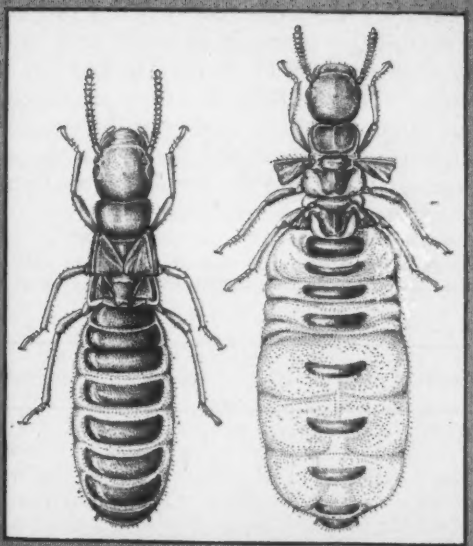
PREVENTING DAMAGE BY TERMITES OR WHITE ANTS



THROUGHOUT the United States native termites, or white ants, cause serious damage to the foundations and woodwork of buildings and articles in the buildings, as well as to living fruit and other trees, crops, and other vegetation. Such damage can be prevented by the proper construction of buildings and by chemical treatments of wood, and injury to growing vegetation by clean culture and the use of insecticides. This bulletin describes the habits and activities of subterranean and nonsubterranean termites and sets forth in detail the precautions to be taken against them and the remedies available for damage which they have inflicted.

This bulletin supersedes Farmers' Bulletin 1037, White Ants as Pests in the United States and Methods of Preventing Their Damage.

Washington, D. C. Issued April, 1926; revised June, 1930

PREVENTING DAMAGE BY TERMITES OR WHITE ANTS

By T. E. SNYDER, *Senior Entomologist, Division of Forest Insects, Bureau of Entomology*

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TERMITES AND THEIR HABITS

DISTRIBUTION AND FORMS

TERMITES, or "white ants," are destructive native insects of which 44 species occur in the United States. They are distributed throughout the country, although in the southern, southwestern, and Pacific coast regions, where both the subterranean and nonsubterranean kinds occur (fig. 1), they are more numerous and injurious than elsewhere.

These so-called white ants are not true ants, although they are superficially antlike and live in colonies made up of different forms or castes. In these nests or colonies both wingless and winged mature individuals are produced. The brownish or blackish, elongate, slender, antlike, colonizing, sexual adults (fig. 2) with long white wings, unlike the other forms, have functional eyes and their bodies are able to endure full sunlight. These migratory males and females appear normally once a year during a short period. There are three stages in the life of white ants: The egg, the immature form (nymph), and the mature individual (including sterile workers (fig. 12, *b*), soldiers (fig. 12, *a*), and the various fertile reproductive forms).

LOCATION OF COLONIES OR NESTS

The nests of some species of termites [1] are in the earth and in dead and decaying wood. These species are of subterranean habit, timber and trees being attacked by the workers only through the ground. The nests of some other species,[2] however, are excavated in wood and trees by the winged forms, there being no workers and no underground life.

With the clearing of land and the consequent destruction of their natural breeding places in the dead trees, decaying stumps, and logs of the forests, termites become increasingly destructive to the woodwork and contents of buildings (figs. 3–9), telephone poles, fences, or any timber in contact with the ground, as well as to living vegetation, including not only fruit and shade trees, shrubs, and flowers, but also truck (fig. 10) and field crops and, in California,

FIG. 1.—Map showing (line AA) the northern limit of damage by subterranean termites in the United States; BB, the northern limit of damage by dry-wood or nonsubterranean termites

grapevines. The principal food of termites is cellulose, which they obtain from either dead or living vegetation.

Termites in the United States are mainly species of subterranean or wood-boring habit and are not so spectacular or common as the mound-making or tree-nesting termites of the Tropics. Very few termites in this country have habits which make them conspicuous, or come above ground into the sunlight, except during the annual colonizing swarm; hence they largely escape notice until they become injurious.

TERMITES WHICH ARE SUBTERRANEAN IN HABIT

Subterranean termites live in forests, building their nests in the wood of standing timber, logs, or stumps, in cleared land, any wood

[1] Genera Reticulitermes Holmgren, Leucotermes Silvestri, Amitermes Silvestri, etc.
[2] Genera Termopsis Heer, Kalotermes Hagen, Neotermes Holmgren, Cryptotermes Banks, etc.

in contact with the ground or, in the plains, in a labyrinth of underground passages in the earth, usually underneath wood or vegetation.

Termites are soft-bodied and always conceal themselves within wood, in the earth, or within their earthlike carton shelter tubes (fig. 11). The grayish-white, soft-bodied, wingless, sterile "workers" (fig. 12, below) are in reality the destructive form. These workers make the excavations occupied by the colony and enlarge and extend them as the colony increases. They live underground or within the wood, are blind, and shun the light; as a result they are rarely seen. In burrowing through wood the workers often completely honeycomb it, usually following the grain and eating out the softer, thin-walled, larger-celled spring or new wood. They are able to penetrate the hardest of woods, provided they have access to moisture in the ground. In extending their galleries in wood and vegetation, subterranean species carry moisture with them by means of moist excrement mixed with earth.

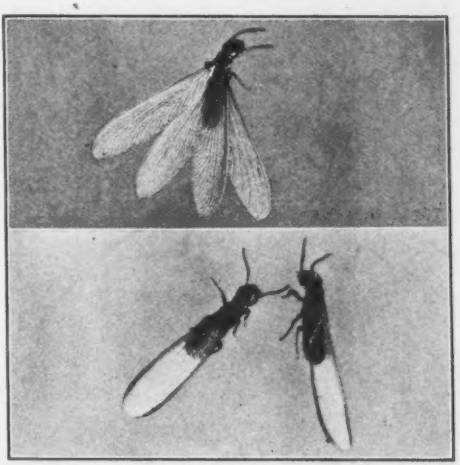

FIG. 2.—Winged sexual adults of eastern subterranean termites; upper, *Reticulitermes virginicus*, nearly 3½ times natural size; lower, *R. flavipes*, enlarged 3 times

TERMITES WHICH ARE NONSUBTERRANEAN IN HABIT

The nonsubterranean termites which are injurious attack wood directly; but, instead of following the grain continuously, they excavate through it longitudinal chambers of limited length. The sexual adults, after they have lost their wings, and the young or nymphs, are the destructive forms. Their pellets of excrement (fig. 13) are regularly impressed, and sometimes completely fill or block up the burrows in a compact mass; they are often expelled as dry droppings from the infested wood. These termites are destructive to the woodwork and furniture in buildings (figs. 14, 15), as well as to living trees. Apparently they can exist without the great amount of moisture necessary to the life of termites which are subterranean in habit.

THE COLONIZING SWARM

At certain seasons, usually spring or fall, but varying with the species and the locality, the winged, sexual individuals migrate in large numbers from the parent nests. They then lose their wings and breed new colonies. In the case of the subterranean termites, wood and trees are usually entered indirectly through the ground,

although sometimes these insects enter trees under bark loosened by sunburn, etc., or through scars or borer holes, provided sufficient moisture is present. Nonsubterranean termites enter the wood directly, or, in the case of trees, through wounds or borer holes or under loose bark; moisture is not necessary.

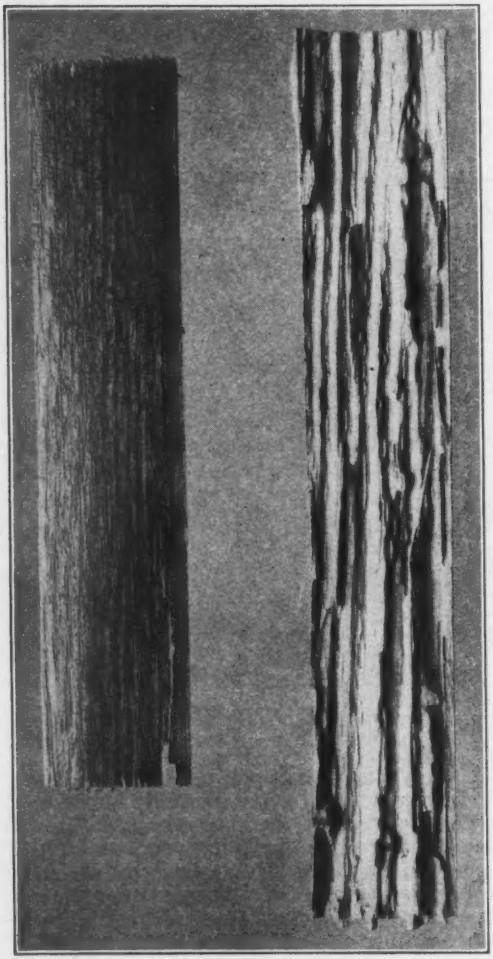

FIG. 3.—Damage to oak flooring by the common eastern subterranean termite *Reticulitermes flavipes*. Note that damage is not apparent on upper surface

In the new quarters eggs are laid, the young develop, and in a few years the colony increases in numbers, and the "workers" are able to feed and care for the reproductive forms—the "king" (title page, left) and "queen" (title page, right)—as well as the soldiers (fig. 12, *a*), which are sterile forms adapted to protect the colony from insect enemies, notably the true ants. In recently formed young colonies the rate of egg laying is slow, but mating is repeated, and, although there is at first a gradual increase, later the increase in the numbers of the broods is rapid. In old colonies there are thousands and tens of thousands of individuals.

Egg laying occurs over a considerable period during the warm months in colonies out of doors. In infested buildings artificially heated, where an even temperature is maintained, the insects are active and may lay eggs every month of the year. The number of eggs laid depends on age.

THE REPRODUCTIVE FORMS

Owing to the increasing number of eggs that develop within her, the queen becomes enlarged, but never loses the power of locomotion. It was once believed that, since the queen mother was the source of the colony life, the termite colony would be exterminated if she were destroyed, but this has been disproved by more recent studies. In addition to the forms that have shed their wings, several different types of reproductive forms occur—forms with wing pads (the undeveloped wings of the nymphs) and wingless reproductive adults. The winged forms, however, are the normal type and occur as a single pair, whereas there may be hundreds of the other forms heading colonies. The reproductive forms with wing pads and the wholly wingless type usually have little color to the body, and the eyes are small. These forms rarely come above ground or leave the burrows in wood.

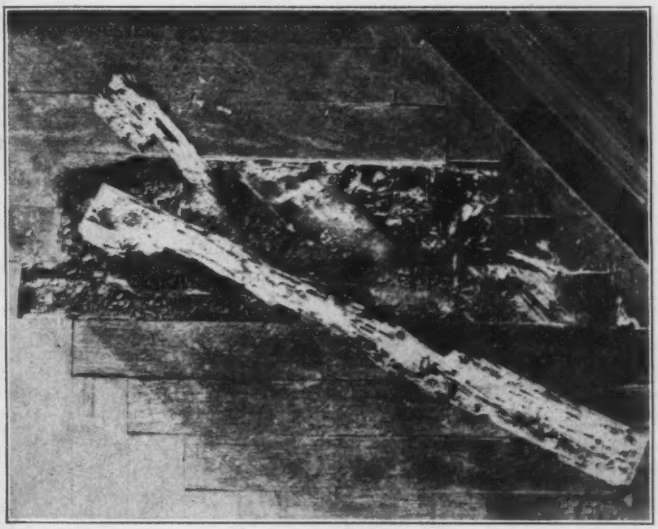

FIG. 4.—Quartered-oak flooring damaged by the subterranean termite *Reticulitermes flavipes* in an infested building, Washington, D. C., 1915

The location of the queens in the colony depends upon the season of the year. During periods of intense heat or drought in the plains or in arid or prairie regions the subterranean termites burrow deeply below ground or to a less depth under stones, cow chips, etc. During winter in the colder climates they burrow below the frost line.

Whole colonies of subterranean termites migrate when conditions become unfavorable. The nonsubterranean termites, on the other hand, are not able to leave the wood in which they have excavated their nests.

PREVENTING AND REMEDYING DAMAGE TO WOODWORK OF BUILDINGS

DESTRUCTION OF BREEDING PLACES ABOUT THE BUILDING SITE

If buildings are to be constructed on recently cleared woodland, decaying logs and stumps should be removed from the soil in the vicinity and burned. If, because of the presence of decaying wood and humus, the subterranean termites are numerous in the earth, the soil should be deeply plowed or otherwise broken up and treated with chemicals to kill the insects. Effective poisons for this purpose are sodium cyanide;[3] a 10 per cent solution of sodium arsenite;[4] kerosene oil; 1 part coal-tar creosote and 3 parts kerosene oil (this mixture should be strained through burlap before use); carbon-disulphide emulsion, which is on the market ready for use; orthodichlorobenzene; lye; or other contact poisons or gases. Live steam forced into the soil will serve the same purpose as the gases. Decaying fence posts, sidewalks, etc., should be removed and replaced with treated wood, concrete, stone, or other resistant substances; such decaying material would facilitate the formation or perpetuation of the termite colonies.

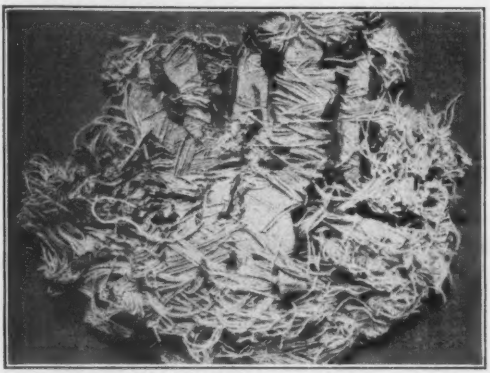

FIG. 5.—Tube of coarse yarn from bale of cotton on floor of building infested by subterranean termites, Greenville, S. C.

PROPER CONSTRUCTION OF BUILDINGS

Termites will infest not only old buildings but also improperly constructed new buildings, and these are often badly infested. It is not the age of the building but the manner in which it has been constructed that renders it liable to attack.

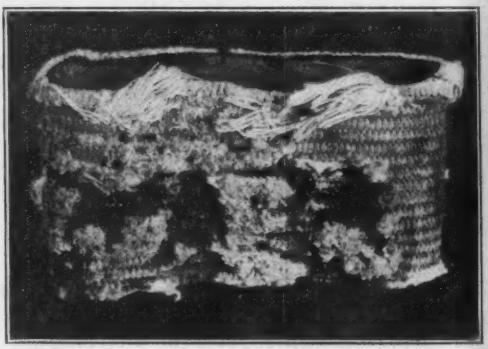

FIG. 6.—Cotton jacket of rubber-lined fire hose from infested building in Missouri, damaged by subterranean termites (*Reticulitermes* sp.)

Insulation.—Complete insulation from the ground of all untreated woodwork of buildings is the only effective permanent remedy

[3] For each acre to be treated, dissolve 160 pounds of granular sodium cyanide in 12,000 gallons of water.

[4] This poison is caustic and should not be used near living vegetation.

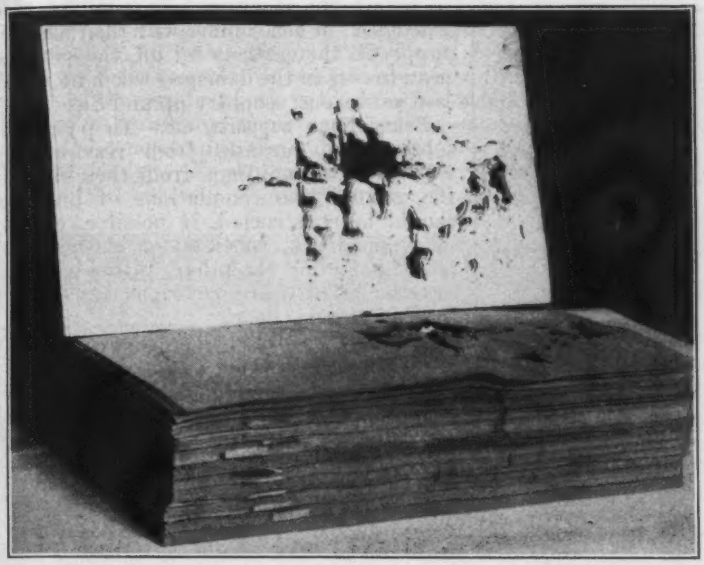

FIG. 7.—Revenue stamps damaged by the subterranean termite *Reticulitermes flavipes* on infested flooring in the Bureau of Engraving and Printing, Washington, D. C., 1921

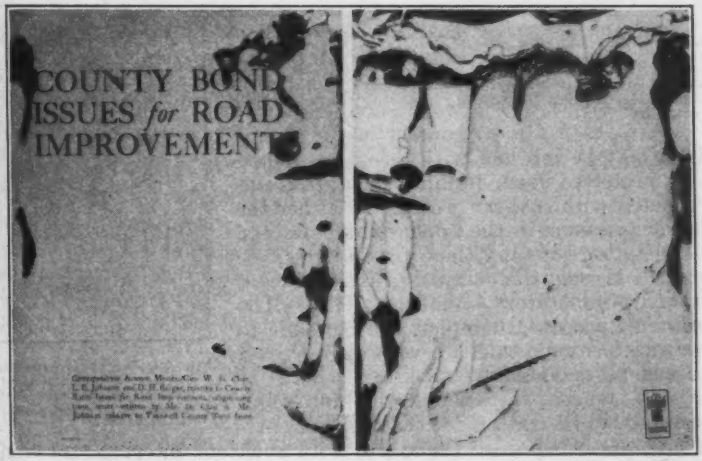

FIG. 8.—Correspondence and advertisement regarding issue of county bonds; damaged by subterranean termites infesting the building in Virginia in which they were stored

against attack by subterranean termites, and the only relief from their presence. These insects must maintain contact with the ground to obtain the moisture necessary for their existence. When contact with their moisture supply in the earth is cut off, the subterranean insects in the damaged wood, no matter how numerous, soon dry up and die.

FIG. 9.—Damage by the subterranean termite *Reticulitermes flavipes* to shoe stored on infested woodwork in a building in New York City

Foundations, supports, etc.—To prevent subterranean termites from reaching the woodwork of buildings from their nests in the ground, the foundations of buildings should be constructed, if possible, entirely of stone, brick, concrete, or concrete and steel,[4] including the pillars in the basement or cellar. The walls, partitions, and flooring in the ground floor, basement, or cellar should also be of concrete. Wooden flooring can be laid over this concrete floor if desired. If the flooring is to be of concrete, the concrete should be laid on a gravel base.

FIG. 10.—Injury to carrots by the subterranean termite *Reticulitermes claripennis*, at Dallas, Tex.

In buildings where stone, brick, or concrete foundations are impracticable, timber impregnated with coal-tar creosote should be employed, and no untreated wood should come in contact with ground which may be infested with termites. Wood to be protected from termites should be impregnated with coal-tar creosote by either the cylinder-pressure or the "open-tank" process. Full details regarding these processes can be obtained from the United States Forest Products Laboratory, Madison, Wis. The open-tank process is simpler, can be made to give satisfactory results where properly used, and can be operated by unskilled labor. If for any reason neither of the foregoing processes can be used, three coats of hot coal-tar creosote brushed on the wood, with sufficient intervals between brushings to permit each coat to dry, will be fairly effective. This

[4] In the Southern States, especially in the subtropics, the more valuable permanent buildings should be constructed entirely of steel and concrete.

method, however, is not generally recommended, since it will preserve the wood for only a few years.

The supports of porches or steps should never be laid directly on the ground, but should rest on rock or concrete. Window sills and frames in the basement or cellar should be laid over concrete and the woodwork should not come in contact with the ground. The supports of the woodwork of coal bins in basements or cellars should not be set in the ground, but should rest on concrete, not extending through the concrete into the soil.

Concrete flooring.—Even in permanent stone or concrete and steel buildings the concrete flooring is often constructed improperly.

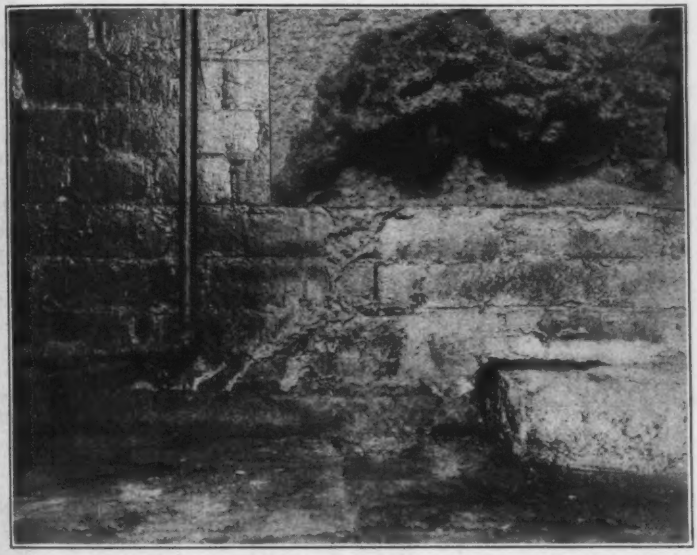

FIG. 11.—Carton, earthlike, shelter tubes constructed by the eastern subterranean termite *Reticulitermes flavipes* over brick wall in dark, heated, damp basement; these tubes are used in passing over impenetrable substances. Inset, near view of tubes to show texture

Usually the base of the concrete floor is a loose combination of coarse gravel or cinders and cement grout. This very rough conglomerate, even if several inches thick, has many cracks and large holes running through it. Over this is laid a layer of solid concrete about 2 or 3 inches thick, of fine texture, in which untreated wooden sleepers are laid while it is still moist. These sleepers nearly or quite reach the coarse, open conglomerate in contact with the earth, and to them is nailed the wooden flooring. (Fig. 17, A.)

It will be seen that this is faulty construction. Termites have free access from the earth, in which they have galleries, through the porous conglomerate, to the untreated beams and flooring. *There should be a layer of solid concrete at least 1 inch thick between the grout and the wood.* (Fig. 17, B.)

Among the commonest means of infestation are wooden sleepers or stringers laid in concrete while the latter is still soft, or placed before the concrete has been poured in. Termites enter through these wooden beams. Other common means of infestation are supports of coal bins extending through concrete and through the disintegrated lime mortar of brick walls.

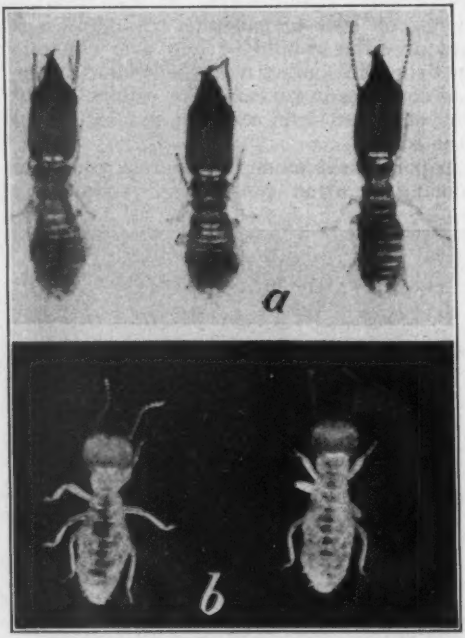

FIG. 12.—Mature soldiers (*a*) and mature workers (*b*) of the eastern subterranean termite *Reticulitermes flavipes*. Slightly more than six times natural size

Termite shields, guards, or metal caps.—The most injurious termites in this country are subterranean in habit and require constant access to the earth in order to attack wood which is either in contact with the earth or which they reach through covered, earthlike shelter tubes constructed over the face of stone, concrete, or brick foundations. In consequence they can be kept out of buildings by means of metal barriers. By simply inserting a sheet of noncorroding metal to serve as a mechanical barrier or "termite shield" into the masonry and turning the projecting edges downward at an angle, communication of termites with the earth, where they obtain moisture, can be cut off. In less pretentious frame buildings, metal caps are placed over the tops of construction stone piling or pillars, or wooden supports. This is a similar method to that used in rat-proofing corn cribs. It is effective and practicable where untreated timber is placed over masonry foundations.

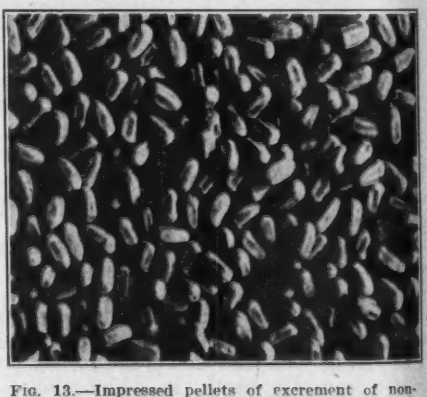

FIG. 13.—Impressed pellets of excrement of nonsubterranean termites (*Kalotermes* sp.), which drop from infested wood. Greatly enlarged

Again, in the case of stone and steel buildings, the steel or stone pillars or piping extending down through the concrete floor to foundations in the earth often make infestation possible, owing to the fact that the concrete floor does not fit tightly about them. Overlapping strips of metal extending horizontally several inches from the pillars or pipes should be imbedded in the concrete floor in order to obtain a tight joint (fig. 17, B); or liquid (adhesive) asphalt should be poured in to plug up the crevice or frame.

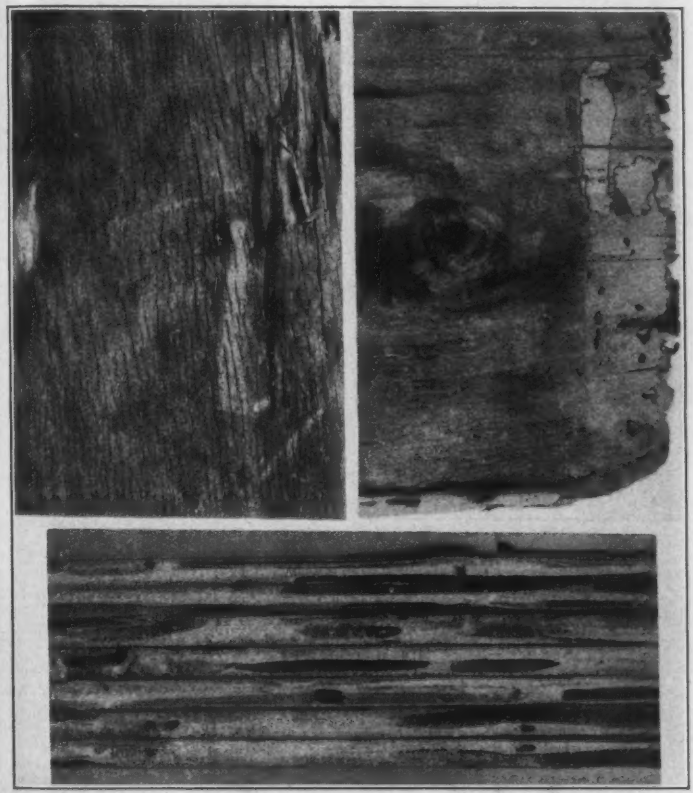

FIG. 14.—Bottom of bureau drawer damaged by the nonsubterranean wood-boring termite *Cryptotermes brevis*, which occurs at Key West, Miami, and Palm Beach, Fla.

Avoiding dampness.—Complete dryness of foundation timbers and basement walls and flooring is an important aid in rendering buildings safe from attack by termites. Dampness, warmth, and darkness attract these insects. A deep air space should be left between the ground and wooden flooring, unless, as in factories, heavy trucking is to be used over the floor, in which case this is impracticable. An air space should be left between the concrete floor and the wooden floor laid over it. Concrete floors should be laid on a gravel

base, which will prevent dampness and cracking. The points of juncture between concrete walls and wooden flooring should be filled in by rounding off the concrete at these places, since cracks often occur where the wall and floor join at right angles. (Fig. 17,

FIG. 15.—Furniture damaged by the nonsubterranean, wood-boring termite *Cryptotermes brevis*, Key West, Fla.

B.) Termites often come up through cracks between walls and flooring.

By mixing a heavy mineral residual oil with Portland cement, a material is formed almost perfectly nonabsorbent of water and therefore excellent for use in damp-proof construction. Where the

various patent or noiseless floorings are used on the ground floor they should always be laid over a concrete base, especially if they contain wood fiber as a constituent.

In no case should untreated beams be completely surrounded with mortar or brick; there should be a space around them sufficient to permit air circulation. Beams should not be set in earth or in moist concrete, but on rock or dry concrete, or in grooves in the latter.

Bungalows or frame buildings which have no cellar should be raised from the ground on stone, concrete, or brick foundations to a height which will allow light and air to penetrate beneath.

Lime mortar.—In brick walls, where lime mortar is used, this sometimes disintegrates after a few years and termites penetrate through the spaces thus left between the bricks, especially where the brickwork is below the ground level. (Fig. 16.) Such walls should be faced with Portland cement 1 inch thick, especially if untreated wood is to come in contact with the bricks.

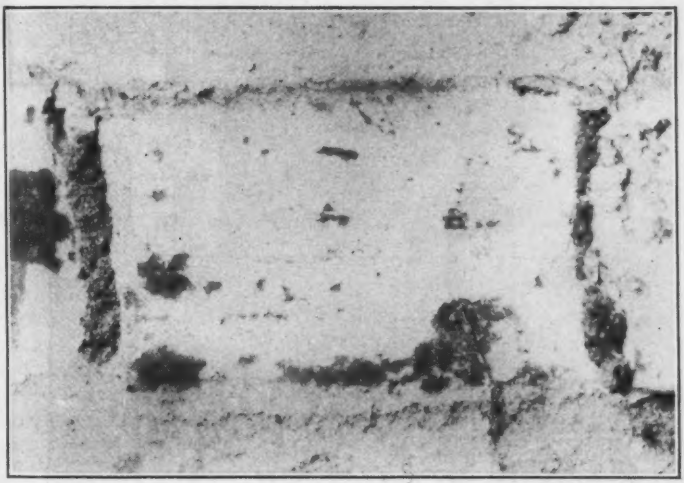

FIG. 16.—Interior view of portion of whitewashed brick foundation wall of building, below ground level, showing shelter tubes of our common subterranean termite (*Reticulitermes* sp.) penetrating the disintegrated lime mortar. These termites came through the earth banked up against the exterior wall. To remedy this condition the exterior wall will have to be faced with concrete for some distance below the ground level

Use of chemically treated wood for interior woodwork, furniture, etc.—In the Southern States, especially in the subtropics, in the more valuable permanent buildings the interior woodwork, furniture, etc., should be impregnated with preservatives, since nonsubterranean termites that attack wood directly are common in those regions. Zinc chloride, bichloride of mercury,[5] sodium fluoride, and chlorinated naphthalene[6] are effective preservatives.

[5] The extremely poisonous character of mercuric chloride renders its use dangerous. It is slowly volatile, and there is a possibility that it will be given off continuously in small quantities from the treated wood. However, it has been extensively used in Germany and apparently without serious consequences.

[6] This preservative is usually referred to as trichlornaphthalene and, as compared with other chemicals, it is really comparable to a technical product having naphthalene, monochloronaphthalene, dichlornaphthalene, and probably some of the higher chlorinations as impurities. Its melting point ranges between 190 and 210° F.—the specification under which it is sold.

Wood-pulp products, such as the various wood-fiber processed or composition boards, for interior finish and substitutes for lath (fig. 18), or for exterior use, can be protected from attack by termites by adding certain poisons, such as crude carbolic acid, to the pulp or laminated boards in the course of manufacture. Available poisons

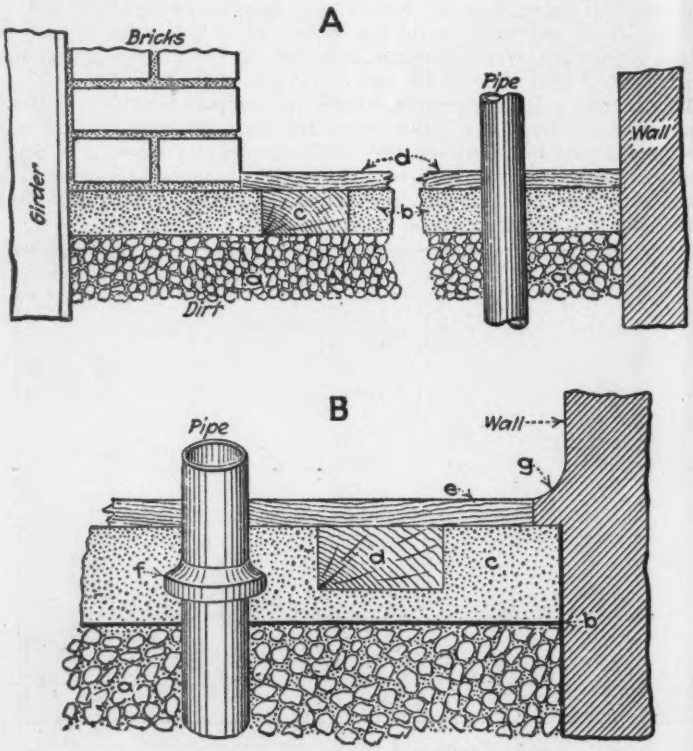

FIG. 17.—A, Improperly constructed concrete flooring: *a*, Gravel or cinders loosely cemented with coarse concrete, 3 inches thick, but with many crevices and holes; *b*, solid, dense concrete, 2 inches thick; *c*, 2 by 4 inch untreated wood sleeper set in moist concrete over the grout; *d*, ⅞-inch pine flooring nailed to sleepers. B, Properly constructed concrete flooring: *a*, Gravel or cinders loosely cemented with coarse concrete, but with many crevices and holes; *b*, asphalt waterproofing ⅛ inch thick; *c*, dense concrete, 3 inches thick; *d*, 2 by 4 inch treated wood sleeper set in a groove in concrete which insulates it from termites in the earth; *e*, ⅞-inch flooring nailed on sleepers; *f*, metal collar around pipe which runs down through the concrete (this collar should be soldered to the pipe and embedded in the concrete); *g*, shoulder of concrete at point of wall and concrete floor to avoid a right-angle connection and consequent cracking

for this purpose are crude carbolic acid at the rate of 1 gallon to 1,000 square feet; bichloride of mercury at the rate of 49 ounces per 1,000 square feet; or copper sulphate at the rate of 113 ounces per 1,000 square feet. Chlorinated naphthalene is a suitable poison for cane-fiber boards.

MODIFICATIONS OF CITY BUILDING CODES

One of the simplest and most effective means of prevention of attack would be to modify the building regulations or codes of various cities so as to include a few simple rules to protect houses from damage by termites. As the principal object in view is to keep all untreated wood from contact with the ground, where the termites live and from which they get their moisture, the regulations should stipulate that no floors, sills, beams, clapboard, etc., of untreated wood may be laid on or in the earth and that untreated beams may not be laid in concrete without at least 1 inch of concrete underneath and separating it from the earth; that in foundations or in cellar walls in contact with the earth a special grade of hard mortar should be used, since lime mortar[7] after some years' service disintegrates; that all brickwork extending below the surface of the ground shall be faced and capped with concrete at least 1 inch thick; and, where nonsubterranean as well as subterranean termites occur, that only woodwork impregnated with preservatives be used for exterior and interior construction, unless it is impracticable to obtain such treated wood.

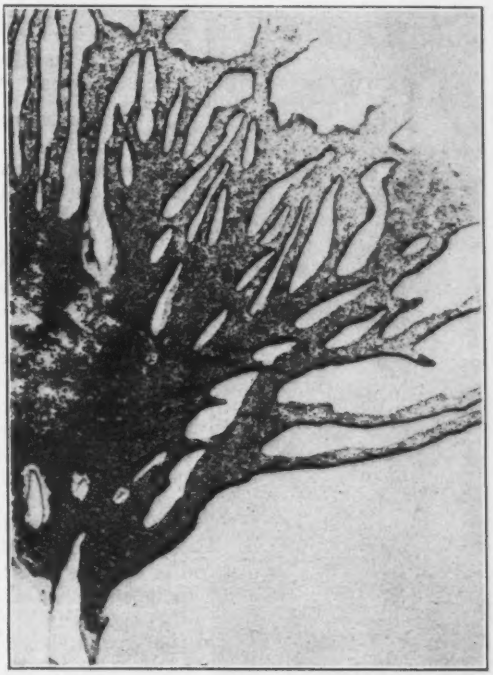

FIG. 18.—Pressed wood-pulp tile mined by subterranean termites infesting the building, Biloxi, Miss.

LOCATING AND TEMPORARILY ARRESTING THE DAMAGE

Although it may be difficult to eliminate termites and stop further damage by them, when once these insects have become established in the woodwork of a building, the approximate point of entrance should be sought at once by careful examination of all woodwork in contact

[7] The Bureau of Standards of the United States Department of Commerce recommends a mortar composed of 1 part Portland cement to 3 parts of sand graded from fine to coarse, with no grains larger than will pass through the No. 10 sieve, to which may be added 10 per cent by weight of the cement of some workability agent, such as hydrated lime, for use in locations where termites abound. Such a mortar, it is believed, will have the desirable properties of both cement and lime mortars and, furthermore, will contain a sufficient quantity of cement to prevent the penetration of it by the termites. (See fig. 16.)

with the ground. To do this, it may be necessary to tear up the foundations, flooring, and some other woodwork. The foundation timbers and interior woodwork found damaged should be removed, and the ground where they were set should be broken up and drenched with some liquid which will kill or at least temporarily prevent the further activity of termites at that point. Any of the insecticides [8] mentioned under the heading "Destruction of breeding places about the building site" (p. 6) will meet the need.

FIG. 19.—Entrance holes of sexual, colonizing adults of a nonsubterranean termite (*Kalotermes hubbardi*) in wood of dead cottonwood tree in Arizona

INDICATIONS OF INFESTATION

The annual emergence of large numbers of the flying termites is an indication as well as a warning that the woodwork is infested, and the point of emergence indicates the approximate location of the infested timbers. Even if the insects are not observed "swarming," large numbers of the dead winged adults or of the discarded wings usually will be found near by. Frass and earth thrown out of crevices through which the insects emerge are also evidences of their presence. Another warning is the presence of branching shelter tubes of small diameter, made of earth mixed with finely powdered wood, on foundation timbers or other woodwork, or over the surface of stone, brick, or other impenetrable foundation material (fig. 11), through which the insects travel from the ground to the woodwork. These tubes should be broken off and the ground where they originate broken up and drenched with one of the liquids named in the paragraph under the heading, "Destruction of breeding places about the building site" (p. 6).

In the case of the nonsubterranean termites, which infest wood directly, evidences that they are damaging wood are the impressed pellets of excrement (fig. 13) which are expelled from the wood. Other evidences are the holes, similar in size to BB shot, where the insects entered the wood. (Fig. 19.)

KILLING THE WINGED ADULTS WILL NOT STOP THE DAMAGE

When efforts are made to prevent further damage by termites in buildings, it should be realized that the numbers of these insects may be constantly recruited from some undiscovered, outside, central colony. The destruction of the winged colonizing adults with house-

[8] If sodium cyanide is used, a strong solution, 1 ounce to a gallon of water, is desirable.

hold ammonia, etc., at the time of emergence, although beneficial in preventing the establishment of new colonies, will not eradicate the insects infesting the woodwork. The most destructive forms are the white, wingless workers, which remain within the wood.

DISCONNECTING WOOD FROM THE GROUND

Subterranean termites infesting beams or other wood will die out if the wood is disconnected from the ground. Knowledge of this fact will save time and expense, especially in the case of old frame buildings, where extensive repairs would be unwarranted. Disconnecting untreated foundation timbers from contact with the soil will also cause the death of subterranean termites in the other woodwork, furniture, and stored material in the building, even if they have penetrated to the second or third floors. These timbers need not be removed or replaced unless seriously weakened structurally. However, if the wood is kept moist by some other means, such as water leakage, the termites will continue to work and thrive. This applies especially to damp corners of basements near outside water pipes, bathrooms, kitchens, and the like.

Wooden floors laid directly on the ground or on stringers on the ground, or set in concrete, should be removed. There should be a layer of concrete between the earth and the wooden floor (fig. 17, B). Wooden baseboards should be removed.

REPLACING WITH CONCRETE

Concrete floors and concrete baseboards should be substituted for wood. Untreated beams penetrating through concrete floors into the earth and the lower parts of door jambs and casings should be cut off at least 6 inches above the ground or floor and replaced with cement plinths, which should project one-quarter inch beyond the jambs and casings. Metal strips should be sunk down from the woodwork into the concrete. Wooden thresholds, wainscoting, window sills, subsills, and stools in the basement or ground floor should be removed and placed on concrete (a layer of concrete between the earth and wood) or replaced with concrete.

REPLACING WITH METAL

In basements and cellars steel rails or other structural metal work can sometimes be economically used to replace weakened timbers.

SPRAYING AND POISONING

Fumigation, poisons, and spraying are of no permanent value against subterranean termites in buildings, since, while they may kill the flying insects and some of those in the wood, others will continue to come up from the ground.

In the case of termites which do not live in the ground, however, but attack wood directly, it is advisable to remove and replace the wood if the damage is slight and localized. Where the wood has been seriously damaged, but not structurally weakened, saturate the infested wood with orthodichlorobenzene. The wood should be thoroughly saturated with this chemical, a rag or mop being used,

dripping wet, or the liquid can be applied as a spray. Several applications may be necessary to kill the insects.

If orthodichlorobenzene is used as a spray, it is advised that the house be opened up before and for some time after treatment, since there is quite an odor to the chemical which may prove disagreeable in a closed room. Also, in spraying timbers overhead care should be taken not to let the liquid drip down, since it might slightly burn the face and hands and would be painful if it got into the eyes.

If the orthodichlorobenzene treatment is not practicable and the wood is too thick for the solution to penetrate, blow dry Paris green by means of a bellows into holes bored with an auger into the infested wood; these holes should penetrate to the galleries of the termites. If, because of moisture, the Paris green becomes caked, the treatment should be repeated. Wood structurally weakened should be removed and replaced with treated wood, discussed in Department Bulletin 1231, or strengthened with structural steel.

By far the greater and more serious damage to timber in the United States is caused by termites of the subterranean type. Department of Agriculture Leaflet 31, on the prevention of damage by termites in buildings, discusses in detail the control of subterranean termites.

PREVENTING AND REMEDYING INJURY TO LIVING VEGETATION

FRUIT, NUT, SHADE, AND FOREST TREES

Termites cause occasional but serious injury to living trees, shrubs, nursery stock, and grapevines. A wise preventive measure is the removal of all loose wood which may afford them shelter, such as prunings, dead and dying trees and the like, and untreated fence posts and similar material. Cleanliness in orchard and forest management is important. Since termites render unmerchantable the forest trees which have been killed by insects, fire, or disease, all timber from such trees should be utilized or removed as promptly as possible.

Covering scars and pruned areas.—To prevent infestation, care should be taken that the trees do not become scarred, especially near the base. Scars and all pruned areas should be treated with a mixture of one-fourth creosote and three-fourths coal tar. This mixture should not be allowed to come in contact with the living tissues at the edges of the bark; to protect them a shellac should be applied.

Commercial fertilizers.—Soil heavily manured will attract subterranean termites, since they can obtain food from the animal manure; commercial fertilizers should be used in preference in regions where termites are common in the soil.

YOUNG PLANTATIONS OR NURSERY STOCK

Injury to nursery stock will be more serious on recently cleared land, to stock from 1 to 3 years old, and where decaying wood is abundant. Any débris in which the insects breed should be removed. In general the use of recently cleared land should be avoided in planting nursery stock. Earth used in banking should be free from rotten wood. Care should be taken not to allow the roots to dry out before planting, as weakened stock is specially susceptible to attack; particular care should be given grafted stock. In the case

of the pecan it is recommended that two or three cereal crops be grown on newly cleared land before the young trees are set out.

Tree surgery.—Properly executed tree surgery [11] sometimes is effective in repairing injury by termites to valuable old fruit and shade trees.

Insecticides.—When valuable trees are infested but not yet dying, subterranean termites can be killed in the soil, if it is moist and not too compact, by breaking it up near the tree and pouring carbon disulphide on the earth at a distance of about a foot from the trunk, then covering the liquid over with earth. The gas from this liquid will penetrate the subterranean galleries of the termites. It is somewhat dangerous to plant life and very large doses should not be used. *Care should be taken in handling this volatile fluid, as the gas or vapor from it is highly inflammable and explosive when mixed with air in certain proportions; no flame should be brought near it, and the fumes should not be inhaled, as they are poisonous.* There are indications that an emulsion of carbon disulphide, which is on the market ready for use, may prove more effective than carbon disulphide alone; as in the case of the disulphide itself, the earth is loosened up and the emulsion poured on, at least a foot from the tree. Carbon tetrachloride,[12] the gas from which is neither explosive nor inflammable, can be similarly used but is apparently not so effective as carbon disulphide. The gases from carbon disulphide and carbon tetrachloride, being heavier than air, will not readily rise.

If tree trunks or branches are infested, they must be treated with poisonous liquids, such as kerosene emulsion poisoned with sodium arsenite.[13] Orthodichlorobenzene is probably useful in the same way. When treating the infested portions, which are usually in the dead heartwood, these liquids must not be permitted to come in contact with living plant tissue.

Where nonsubterranean termites are infesting living trees, they can be poisoned with dry Paris green in the manner discussed on page 18.

VINEYARDS

In vineyards all dead or diseased vines should be removed. All exposed areas left by pruning should be painted with preservative coatings and the prunings should be burned promptly. Near-by stands of tree windbreaks should be carefully cared for and kept free from infestation by termites. Trellis posts should be creosoted.

FIELD AND TRUCK CROPS

Deep fall plowing.—Deep, late, fall plowing will be of value in breaking up the galleries and nests of subterranean termites on ground planted to field or truck crops. Irrigation of the land, where practicable, will be effective; this can be done before planting the crop.

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[11] For information on this subject the reader is referred to Farmers' Bulletin 1178, "Tree Surgery," which may be obtained on application to the United States Department of Agriculture.

[12] Carbon tetrachloride is a thin, transparent, colorless, volatile liquid, which forms a gas with a pungent, aromatic odor. Like carbon disulphide it is heavier than air. Although it is only about one-half or one-third as effective as carbon disulphide when used at the same dosage rate, it has the great advantage that its gas is neither explosive nor inflammable; there will be no fire risk attending its use in buildings.

[13] In each gallon of the water used for diluting kerosene emulsion or miscible oil, dissolve 1 ounce of sodium arsenite.

Burning stubble.—Care should be taken not to plow under stubble which will serve as food for termites; it should be burned. The use of commercial fertilizers instead of animal manure is also recommended where subterranean termites are common in the soil.

Insecticides.—Injury to corn in the prairie region of Kansas has resulted from the presence of termites in enormous numbers in the heavily sodded soil, where they feed on the roots of the vegetation. Such soil should be plowed up and treated with insecticides before crops are planted; effective insecticides are sodium arsenite and sodium cyanide. (See p. 6.)

Rotation of crops.—As a result of the frequent stirring of the soil, rotation of crops will aid in preventing termites from injuring them.

FLOWERS AND GREENHOUSE STOCK

Termites injure a great variety of flowers in gardens, as well as many plants grown under glass in greenhouses, where the warm, moist atmosphere maintained throughout the year promotes greatly the activity of the insects. Injury from termites is especially common where the plants are perennial and have woody stalks.

Sources of infestation.—Heavily manured flower beds are a source of infestation to the stems of the flowers, as well as to the woodwork of buildings near by, if suitable protection is lacking. Untreated wooden stakes used as supports of plants often become infested, and in time the insects attack the plants. In greenhouses termites often attack old label sticks, the wooden uprights supporting wooden benches set on or in the ground, and the wooden bench bottoms and plant pots, and later attack the growing plants. The insects come up through the ground and form dirt galleries over the supports, or burrow up through the wooden bench legs and run galleries the full length of the benches. They enter the soil in the pots through the drainage holes and eat out the main stalk of the root, killing the plant very quickly.

Proper construction of greenhouses.—Proper construction of greenhouses will practically safeguard plants growing in them from all injury by termites. Iron frames and concrete work should, wherever possible, replace bricks or woodwork. In cases of infestation of old greenhouses all wooden uprights supporting wooden plant benches should be sawed off, if set on or in the ground, and rested on stone, bricks, or concrete, above the surface of the ground. Proper repairing, including the removal of all infested wood, will prevent the plants from becoming infested in turn. Where woodwork is necessary the wood should be impregnated with zinc chloride or bichloride of mercury; it can be painted after treatment. Wood impregnated with coal-tar creosote can not be used with safety in greenhouses.

Avoiding stable manure.—In flower gardens, especially those located near the woodwork of buildings, commercial fertilizers should be substituted for stable manure in order to protect not only the buildings but also the growing plants.

Insecticides.—Either carbon disulphide or carbon tetrachloride[14] can be used to kill termites in the soil if it is moist and not compact. Small holes should be made near the infested plants and a small

[14] See footnote 12, (p. 19).

quantity of the liquid chosen poured in and the holes immediately closed tightly with earth. Calcium cyanide[15] has also been found effective, but it should not be placed near living plants; it mixes readily with and enriches the soil and gives off an insecticidal gas which *should not be inhaled, as it is poisonous.*

An effective control may be found in the use of kerosene nicotine oleate or a 5 per cent kerosene emulsion.[16] If the greenhouse benches are infested, but for any reason can not be replaced, they should be soaked thoroughly with this emulsion, as should also the ashes and sand under the pots on the benches. This may be done by removing the potted plants from a section of the bench, spraying that section, and moving the pots on the bench to cover the treated area, thus giving access to another section. Potted heliotropes and geraniums have been treated directly with the 5 per cent kerosene emulsion without injury to the plants, and the white ants in the soil of the pots were all killed. The soil should be wet down before this spray is used. This treatment should be given late in the afternoon and be followed early the next morning with a thorough syringing of the soil with water to wash out the surplus oil. It is important to remove all infested pots from the bench as soon as the infestation is noticed and to destroy the termites with kerosene emulsion.

SUMMARY

Damage by termites or "white ants" is serious to many classes of crude and finished forest products and is occasionally serious to living trees and other plants. These insects are especially injurious to foundation timbers, the woodwork of buildings, and material stored in buildings to which they have gained entrance. Damage to timber in contact with the ground is especially serious in the Southern, Central, and Pacific Coast States, and the tropical possessions of the United States.

The woodwork of buildings can be protected from the attack of termites by proper construction and by the use of wood treated with preservatives. These insects can be eliminated where already established in buildings by removing wood in contact with the ground and replacing it with wood chemically treated.

To construct buildings so that they will be white-ant proof, make their foundations, where possible, entirely of stone, brick, or concrete, including stone or metal columns or pillars in the basement to support the floor above; make concrete walls and flooring in basement or cellar, and lay concrete floors on a gravel base. Where stone or concrete foundations are impracticable, use timber impregnated with coal-tar creosote.

Lay basement-window sills and frames over concrete, and do not allow woodwork to come in contact with the ground. Never sink untreated timber in the ground or in moist concrete.

Complete dryness of the foundation and of the basement walls and flooring is an important means of rendering buildings safe from

[15] Two ounces of calcium cyanide to 1 square yard of ground is recommended.

[16] Kerosene emulsion is made as follows: Kerosene, 2 gallons; fish-oil soap, one-half pound; water, 1 gallon. Dissolve the soap in hot water and pour in the oil slowly, with constant stirring to emulsify.

Dilution: If 37 gallons of water be added to the above stock emulsion it will give 40 gallons of 5 per cent kerosene emulsion.

attack. Provide for air spaces between the ground and wooden flooring and lay concrete floors on a gravel base.

In regions where nonsubterranean termites are common (see map, fig. 1) woodwork should be treated with preservatives.

To eliminate termites already established in buildings, examine the foundation timbers and other woodwork in the basement to determine the approximate point of entrance and the extent of damage already accomplished. After removing the damaged wood, drench the ground with insecticides or poisonous solutions. Then replace the damaged timber with rock, brick, concrete, or metal work, or substitute, for the foundation, timbers impregnated with coal-tar creosote.

Since subterranean termites always require access to damp earth, shut off this source of moisture. The insects will then be unable to extend their galleries farther and will perish.

Nonsubterranean termites can be killed in infested wood by the use of insecticides.

Injury to living vegetation is occasionally serious, especially in the Southern States, the Southwest, and the Pacific Coast States. It can be prevented by clean cultural methods, deep fall plowing, and the use of insecticides.

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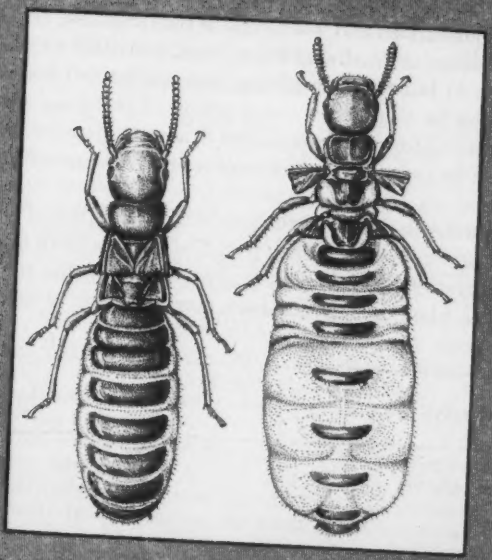
PREVENTING DAMAGE BY TERMITES OR WHITE ANTS



THROUGHOUT the United States, but especially in the Southern, Central, Southwestern, and Pacific Coast States, native termites, or white ants, cause serious damage to the foundations and woodwork of buildings and articles in the buildings, and to living trees, crops, and other vegetation. Damage to buildings, furniture, and similar articles can be prevented by the proper construction of buildings and the chemical treatment of wood, and injury to growing vegetation can be reduced by clean culture and the use of insecticides.

This bulletin describes the habits and activities of subterranean and nonsubterranean termites and sets forth in detail the precautions to be taken against them and the remedies available when damage has been done.

Washington, D.C. Issued April 1926; revised July 1934

PREVENTING DAMAGE BY TERMITES OR WHITE ANTS

By T. E. SNYDER, *senior entomologist, Division of Forest Insects, Bureau of Entomology*

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TERMITES AND THEIR HABITS

DISTRIBUTION AND FORMS

THE TERMITES, or "white ants", in this country are mostly destructive native insects. Fifty-six species of them occur in the United States. They are distributed throughout the country, although in the southern, southwestern, and Pacific coast regions, where both the subterranean and nonsubterranean kinds occur (fig. 1), they are more numerous and injurious than elsewhere.

These so-called "white" ants are not true ants, although they look like ants and live in colonies made up of different forms or castes. In these nests or colonies both wingless and winged mature individuals are produced. The brownish or blackish, elongate, slender, antlike, colonizing, sexual adults (fig. 2) with long white wings, unlike the other forms, have functional eyes, and their bodies are able to endure full sunlight. These migratory males and females appear normally once a year during a short period.

There are three stages in the life of termites—the egg, the nymph, and the adult. The adults are of two kinds—sterile and fertile. The sterile adults of our common subterranean termites and of many other species include two forms (or castes)—the soldiers (fig. 3, *a*) and the workers (fig. 3, *b*); and the fertile or sexual adults include three normal forms (fig. 4, *F* to *K*).

LOCATION OF COLONIES OR NESTS

The nests of some species of termites [1] are in the earth and in dead and decaying wood. These more common and injurious species are of subterranean habit, timber and trees being attacked by the workers only through the ground. The nests of some other less common species,[2] however, are excavated in wood and trees by the winged forms, there being no workers and no underground life.

[1] Genera *Reticulitermes* Holmgren, *Heterotermes* Froggatt, *Amitermes* Silvestri, etc.
[2] Genera *Termopsis* Heer, *Kalotermes* Hagen, *Neotermes* Holmgren, *Cryptotermes* Banks, etc.

With the clearing of land and the consequent destruction of their natural breeding places in the dead trees, decaying stumps, and logs of the forests, termites become increasingly destructive to the woodwork and contents of buildings (figs. 5–11), telephone poles, fences, or any timber in contact with the ground, as well as to living vegetation, including not only fruit and shade trees, shrubs, and flowers, but also truck (fig. 12) and field crops and, in California, grapevines. The principal food of termites is cellulose, which they obtain from either dead or living vegetation.

Termites in the United States are mainly species of subterranean or wood-boring habit and are not so spectacular or common as the mound-making or tree-nesting termites of the Tropics. Very few termites in this country have habits that make them conspicuous, or come above ground into the sunlight except during the annual coloniz-

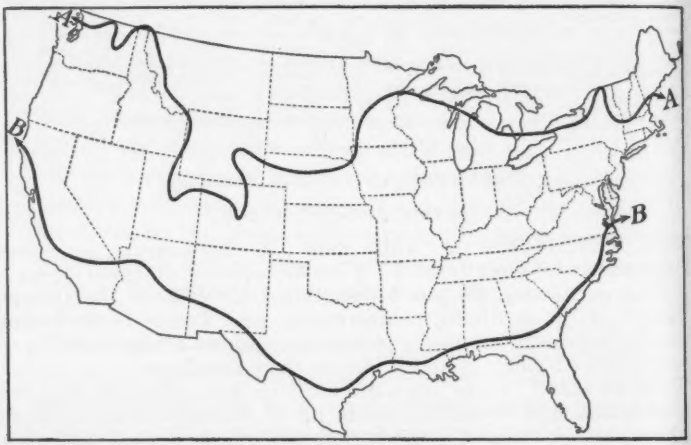

FIGURE 1.—Map showing (line *A–A*) the northern limit of damage done by subterranean termites in the United States and (line *B–B*) the northern limit of damage done by dry-wood or nonsubterranean termites.

ing swarm; hence they largely escape notice until they become injurious.

TERMITES THAT ARE SUBTERRANEAN IN HABIT

Subterranean termites live in forests, building their nests in the wood of standing timber, logs, or stumps; in cleared land, in any wood in contact with the ground; or, in the plains, in a labyrinth of underground passages in the earth, usually underneath wood or vegetation.

Termites are soft-bodied and always conceal themselves within wood, in the earth, or within their earthlike carton shelter tubes (fig. 13). The grayish-white, soft-bodied, wingless, sterile "workers" (fig. 3, *b*) are in reality the destructive form. These workers make the excavations occupied by the colony and enlarge and extend them as the colony increases. They live underground or within the wood, are blind, and shun the light; as a result they are rarely seen. In burrowing through wood the workers often completely honeycomb it, usually following the grain and eating out the softer, thin-walled

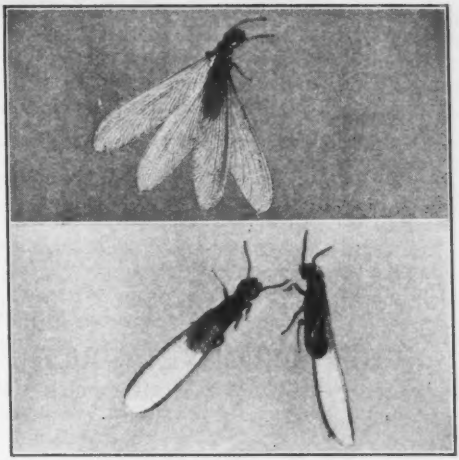

FIGURE 2.—Winged sexual adults of eastern subterranean termites; upper, *Reticulitermes virginicus*, nearly three and one-half times natural size; lower, *R. flavipes*, three times natural size.

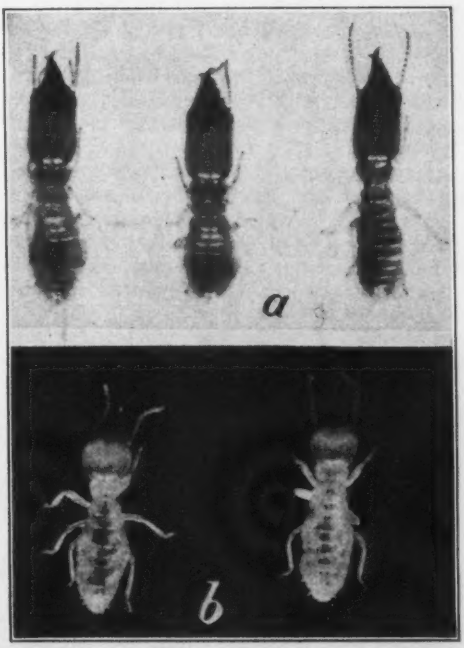

FIGURE 3.—Mature soldiers (*a*) and mature workers (*b*) of the eastern subterranean termite *Reticulitermes flavipes*. Slightly more than six times natural size.

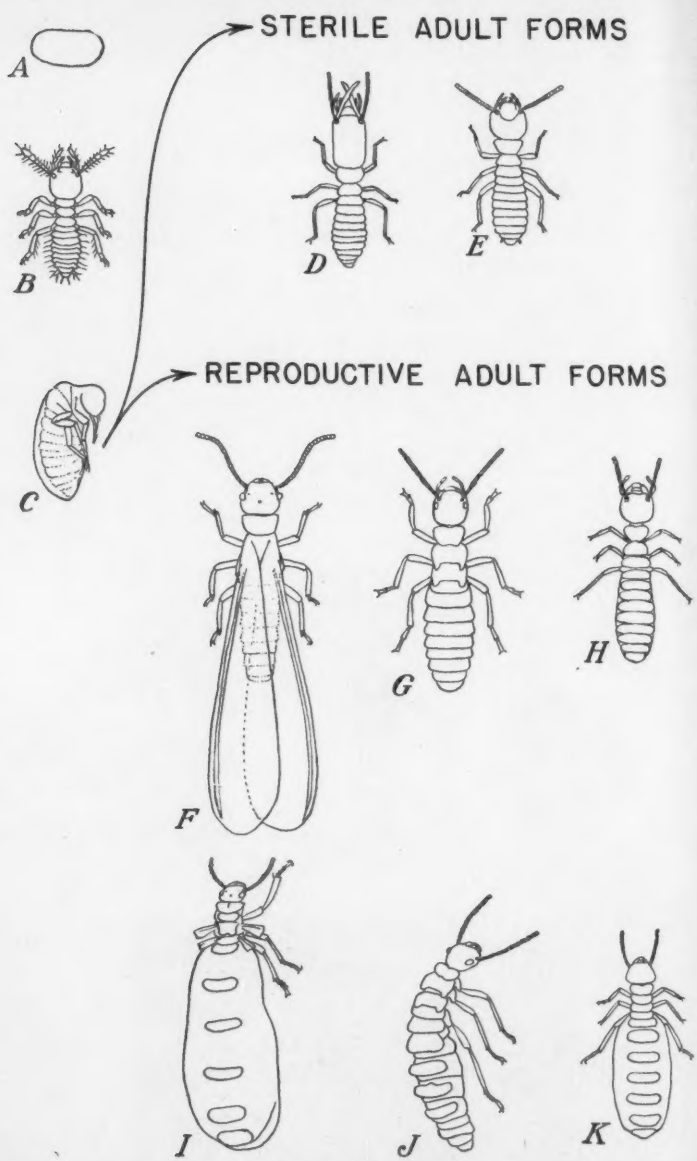

FIGURE 4.—Diagram showing the relationships of the stages and forms of our common subterranean termite *Reticulitermes flavipes*: *A*, Egg; *B*, recently hatched nymph; *C*, mature nymph in quiescent or resting stage; *D*, soldier; *E*, worker; *F*, sexual winged adult; *G*, sexual adult with wing pads; *H*, workerlike wingless sexual adult; *I*, *J*, and *K*, enlarged egg-laying females or queens, corresponding to *F*, *G*, and *H*, respectively. *D* and *E* are sterile adult forms; *F*, *G*, *H*, *I*, *J*, and *K* are fertile or reproductive adult forms. (The enlargements are approximately as follows: *A*, ×16; *B*, ×13½; C, ×10; *D*, ×4½; *E*, ×5½; *F*, ×6; *G*, ×4½; *H*, ×5; *I*, ×2½; *J*, ×2¾; *K*, ×3.)

larger-celled spring or new wood. They are able to penetrate the hardest of woods, provided they have access to moisture in the ground. In extending their galleries in wood and vegetation, subterranean species carry moisture with them by means of moist excrement mixed with earth.

TERMITES THAT ARE NONSUBTERRANEAN IN HABIT

The nonsubterranean termites which are injurious attack wood directly; but, instead of following the grain continuously, they excavate through it longitudinal chambers of limited length. The sexual adults, after they have lost their wings, and the young or nymphs, are the destructive forms. Their pellets of excrement (fig. 14) are regularly impressed, and sometimes completely fill or block up the burrows in a compact mass; they are often expelled as dry droppings from the infested wood. These termites are destructive to the woodwork and furniture in buildings (fig. 15), as well as to living trees. Apparently they can exist without the great amount of moisture necessary to the life of termites which are subterranean in habit.

THE COLONIZING SWARM

At certain seasons, usually spring or fall, but varying with the species and the locality, the winged, sexual individuals migrate in large numbers from the parent nests. They then lose their wings and breed new colonies. In the case of the subterranean termites, wood and trees are usually entered indirectly through the ground, although sometimes these insects enter trees under bark loosened by sunburn, etc., or through scars or borer holes, provided sufficient moisture is present. Nonsubterranean termites enter the wood directly, or, in the case of trees, through wounds or borer holes or under loose bark; moisture is not necessary.

In the new quarters eggs are laid, the young develop, and in a few years the colony increases in numbers, and the workers are able to feed and care for the reproductive forms—the "king" (title page, left) and "queen" (title page, right)—as well as the soldiers (fig 3, *a*), which are sterile forms adapted to protect the colony from insect enemies, notably the true ants. In recently formed young colonies the rate of egg laying is slow, but mating is repeated, and, although there is at first a gradual increase, later the increase in the numbers of the broods is rapid. In old colonies there are thousands and tens of thousands of individuals.

Egg laying occurs over a considerable period during the warm months in colonies out of doors. In infested buildings artificially heated, where an even temperature is maintained, the insects are active and may lay eggs every month of the year. The number of eggs laid depends on the age of the queen.

THE REPRODUCTIVE FORMS

Owing to the increasing number of eggs that develop within her the queen becomes enlarged, but never loses the power of locomotion. It was once believed that, since the queen mother was the source of the colony life, the termite colony would be exterminated if she were destroyed, but this has been disproved by more recent studies. In addition to the forms that have shed their wings, several different types of reproductive forms occur—forms with wing pads (the undeveloped wings of the nymphs) and wingless reproductive adults.

The winged forms, however, are the normal type and occur as a single pair, whereas there may be hundreds of the other forms heading colonies. The reproductive forms with wing pads and the wholly wingless type usually have little color in the body, and the eyes are

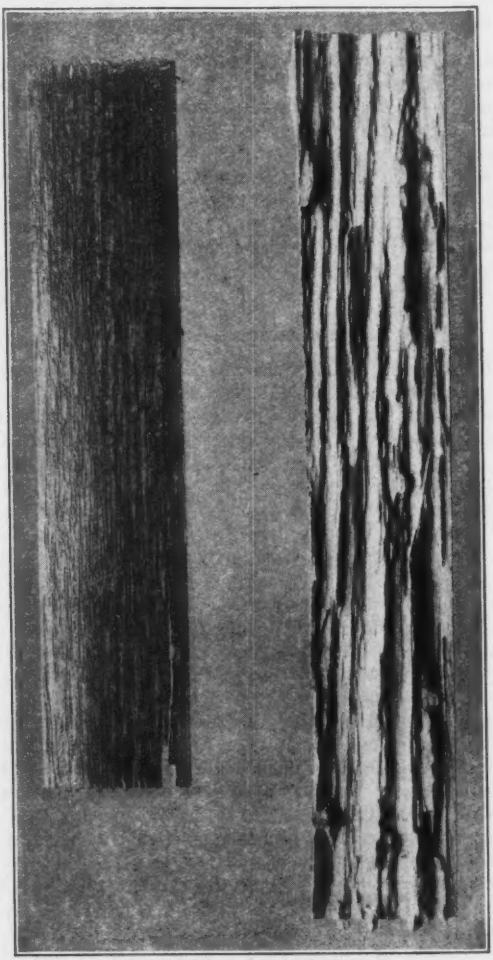

FIGURE 5.—Damage to oak flooring done by the common eastern subterranean termite *Reticulitermes flavipes*. Note that damage is not apparent on the upper surface.

small. These forms rarely come aboveground or leave the burrows in wood.

The location of the queens in the colony depends upon the season of the year. During periods of intense heat or drought in the Plains or in arid or prairie regions the subterranean termites burrow deeply below ground or to a less depth under stones, cow chips, etc. During the winter in the colder climates they burrow below the frost line.

Whole colonies of subterranean termites migrate when conditions become unfavorable. The nonsubterranean termites, on the other

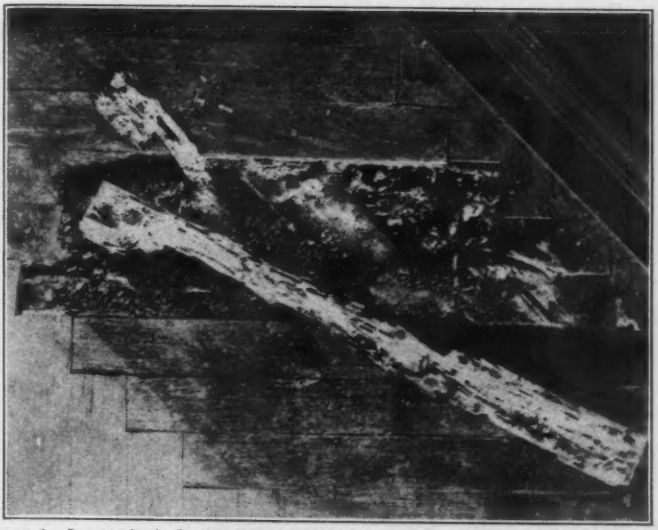

FIGURE 6.—Quartered-oak flooring damaged by the subterranean termite *Reticulitermes flavipes* in an infested building, Washington, D.C., 1915.

hand, are not able to leave the wood in which they have excavated their nests.

PREVENTING AND REMEDYING DAMAGE TO WOODWORK OF BUILDINGS

DESTRUCTION OF BREEDING PLACES ABOUT THE BUILDING SITE

If buildings are to be constructed on recently cleared woodland, decaying logs and stumps should be removed from the soil in the vicinity and burned. If, because of the presence of decaying wood and humus, the subterranean termites are numerous in the earth, the soil should be deeply plowed or otherwise broken up and treated with chemicals to kill the insects. Effective poisons for this purpose are a 10-percent solution of sodium arsenite;[3] 1 part coal-tar creosote and 3 parts kerosene oil (this mixture should be strained through burlap before

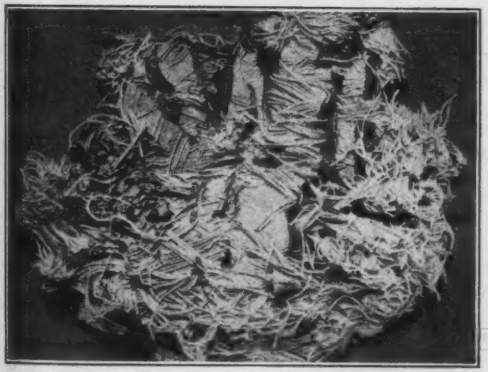

FIGURE 7.—Tube of coarse yarn from bale of cotton on floor of building infested by subterranean termites, Greenville, S.C.

[3] This poison is caustic and should not be used near living vegetation.

being used); carbon disulphide emulsion, which is on the market ready for use; orthodichlorobenzene (50 gallons per 1,000 square feet). Live steam forced into the soil will serve the same purpose as the gases. Decaying fence posts, sidewalks, etc., should be removed and replaced with treated wood, concrete, stone, or other resistant substances; such decaying material would facilitate the formation or perpetuation of the termite colonies.

PROPER CONSTRUCTION OF BUILDINGS

Termites will infest not only old buildings but also improperly constructed new buildings, and these are often badly infested. It is not the age of the building but the manner in which it has been constructed that renders it liable to attack.

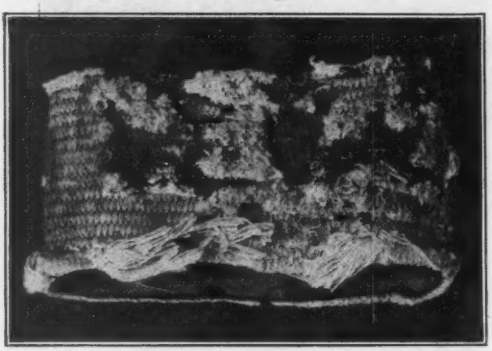

FIGURE 8.—Cotton jacket of rubber-lined fire hose from infested building in Missouri, damaged by subterranean termites (*Reticulitermes* sp.).

INSULATION

Complete insulation from the ground of all untreated woodwork of buildings is the only effective permanent remedy against attack by subterranean termites, and the only relief from their presence. These insects must maintain contact with the ground to obtain the moisture necessary for their existence. When contact with their moisture supply in the earth is cut off, the subterranean insects in the damaged wood, no matter how numerous, soon dry up and die.

FOUNDATIONS, SUPPORTS, ETC.

To prevent subterranean termites from reaching the woodwork of buildings from their nests in the ground, the foundations of buildings should be constructed, if possible, entirely of stone, brick, concrete, or concrete and steel,[4] including the pillars in the basement or cellar. The walls, partitions, and flooring in the ground floor, basement, or cellar should also be of concrete. Wooden flooring can be laid over this concrete floor if desired. If the flooring is to be of concrete, the concrete should be laid on a gravel base.

In buildings where stone, brick, or concrete foundations are impracticable, timber impregnated with coal-tar creosote should be employed, and no untreated wood should come in contact with ground which may be infested with termites. Wood to be protected from termites should be impregnated with coal-tar creosote by either the cylinder-pressure or the open-tank process. Full details regarding

[4] In the Southern States, especially in the subtropics, the more valuable permanent buildings should be constructed entirely of steel and concrete.

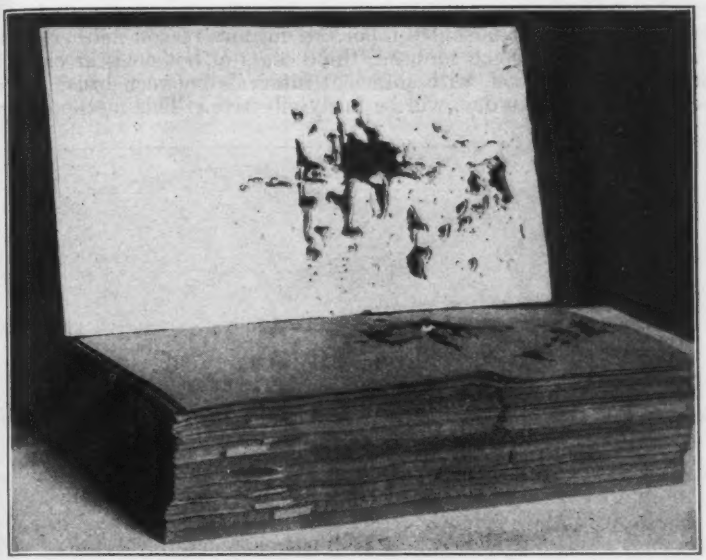

FIGURE 9.—Revenue stamps damaged by the subterranean termite *Reticulitermes flavipes* on infested flooring in the Bureau of Engraving and Printing, Washington, D.C., 1921.

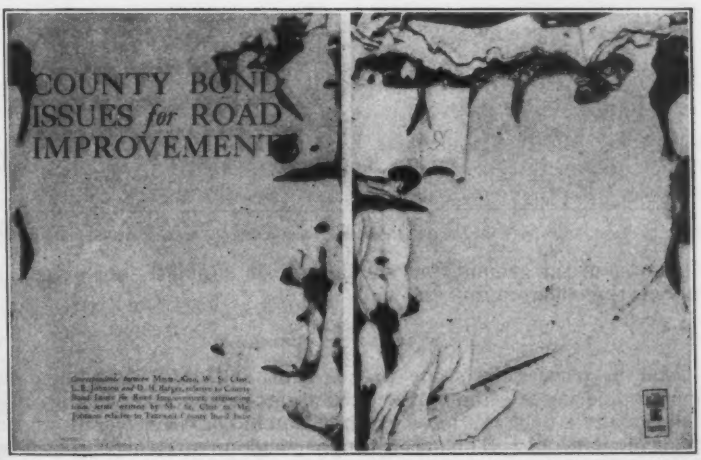

FIGURE 10.—Correspondence and advertisement regarding issue of county bonds; damaged by subterranean termites infesting the building in Virginia in which they were stored.

these processes can be obtained from the United States Forest Products Laboratory, Madison, Wis. The open-tank process is simpler, can be made to give satisfactory results where properly used, and can be operated by unskilled labor. If for any reason neither of the foregoing processes can be used, three coats of hot coal-tar creosote brushed on the wood, with sufficient intervals between brushings to permit each coat to dry, will be fairly effective. This method, however, is not generally recommended, since it will preserve the wood for only a few years.

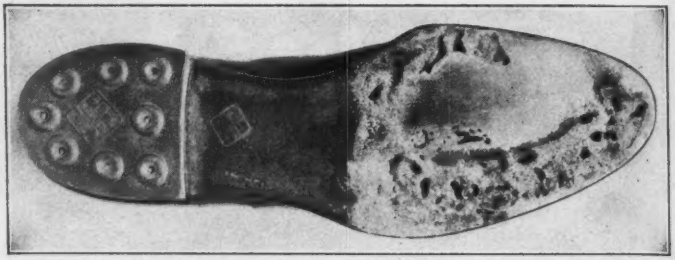

FIGURE 11.—Damage done by the subterranean termite *Reticulitermes flavipes* to shoe stored on infested woodwork in a building in New York City.

The supports of porches or steps should never be laid directly on the ground, but should rest on rock or concrete. Window sills and frames in the basement or cellar should be laid over concrete and the woodwork should not come in contact with the ground. The supports of the woodwork of coal bins in basements or cellars should not be set in the ground, but should rest on concrete, not extending through the concrete into the soil.

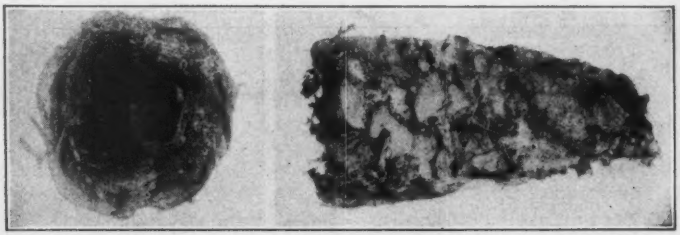

FIGURE 12.—Injury to carrots caused by the subterranean termite *Reticulitermes claripennis*, at Dallas, Tex.

CONCRETE FLOORING

Even in permanent stone or concrete and steel buildings the concrete flooring is often constructed improperly. Usually the base of the concrete floor is a loose combination of coarse gravel or cinders and cement grout. This very rough conglomerate, even if several inches thick, has many cracks and large holes running through it. Over this is laid a layer of solid concrete about 2 or 3 inches thick, of fine texture, in which untreated wooden sleepers are laid while it is still moist. These sleepers nearly or quite reach the coarse, open

conglomerate in contact with the earth, and to them is nailed the wooden flooring (fig. 16, *A*).

It will be seen that this is faulty construction. Termites have free access from the earth, in which they have galleries, through the porous conglomerate, to the untreated beams and flooring. *There should be a layer of solid concrete at least 1 inch thick between the grout and the wood* (fig. 16, *B*).

Among the commonest means of infestation are wooden sleepers or stringers laid in concrete while the latter is still soft, or placed before

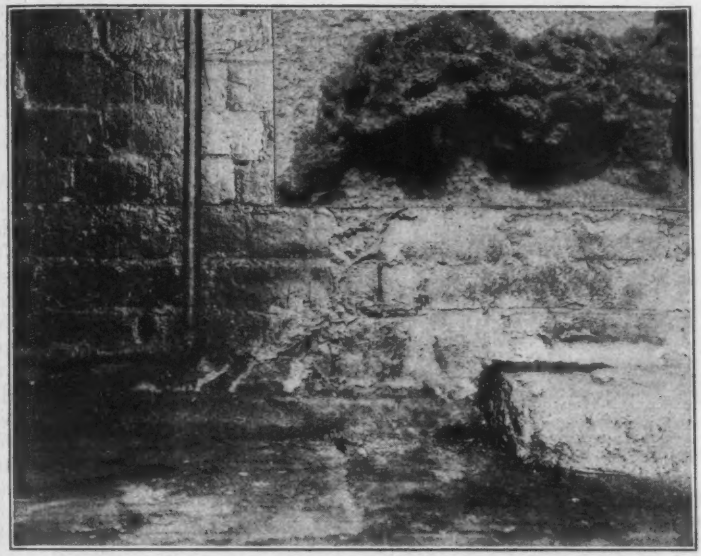

FIGURE 13.—Carton, earthlike, shelter tubes constructed by the eastern subterranean termite *Reticulitermes flavipes* over brick wall in dark, heated, damp basement; these tubes are used in passing over impenetrable substances. Inset, near view of tubes showing texture.

the concrete has been poured in. Termites enter through these wooden beams. Other common means of infestation are supports of coal bins extending through concrete and through the disintegrated lime mortar of brick walls.

TERMITE SHIELDS, GUARDS, OR METAL CAPS

Subterranean termites require constant access to soil moisture in order to attack wood. This requirement is supplied when wood is either in contact with the soil or when the termites can reach it through covered, earthlike shelter tubes. These shelter tubes may be constructed over the face of stone, concrete, or brick foundations and along water pipes or similar structures. In consequence they can be kept out of buildings by means of metal barriers. By firmly inserting a sheet of galvanized iron or "termite shield" in the surface of the masonry and letting it project horizontally for 2 inches, then turning the projecting part downward at an angle, communication of termites with the soil, where they obtain moisture, can be cut off. In

less pretentious frame buildings, metal caps should be placed over the tops of all construction stone piling or pillars.

This method is similar to that used in rat-proofing corncribs. It is effective and practicable where untreated timber is placed over masonry foundations.

Again, in the case of stone and steel buildings, the steel or stone pillars or piping extending down through the concrete floor to foundations in the earth often make infestation possible, owing to the fact that the concrete floor does not fit tightly about them. Overlapping strips of metal extending horizontally several inches from the pillars or pipes should be imbedded in the concrete floor in order to obtain a tight joint (fig. 16, *B*); or coal-tar pitch should be poured in to plug up the crevice or frame.

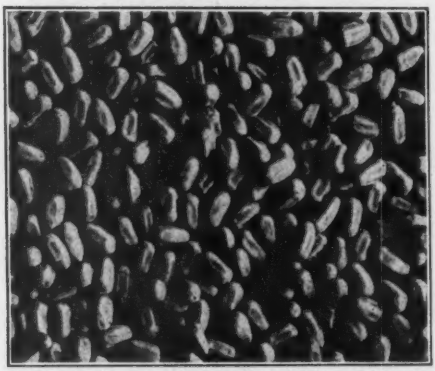

FIGURE 14.—Impressed pellets of excrement of nonsubterranean termites (*Kalotermes* sp.), which drop from infested wood. Greatly enlarged.

AVOIDING DAMPNESS

Dry foundation timbers and basement walls and flooring are important aids in rendering buildings safe from attack by termites. Dampness, warmth, and darkness are favorable to these insects. Concrete floors should be laid on a gravel base, which will prevent dampness and cracking. The points of juncture between concrete walls and wooden flooring should be filled in by rounding off the concrete at these places, since cracks often occur where the wall and floor join at right angles (fig. 16, *B*). Termites often come up through cracks between walls and flooring.

By mixing a heavy mineral residual oil with portland cement, a material is formed almost perfectly nonabsorbent of water and therefore excellent for use in damp-proof construction. Where the various patent or noiseless floorings are used on the ground floor they should always be laid over a concrete base, especially if they contain wood fiber as a constituent.

In no case should untreated beams be completely surrounded with mortar or brick; there should be a space around them sufficient to permit air circulation. Beams should not be set in earth or in moist concrete, but on rock or dry concrete, or in grooves in the latter.

Bungalows or frame buildings which have no cellar should be raised from the ground on stone, concrete, or brick foundations to a height which will allow light and air to penetrate beneath.

LIME MORTAR

Lime mortar sometimes disintegrates after a few years, and termites penetrate through the spaces thus left between the bricks, tiles, etc. Where lime mortar is used below the ground level (fig. 17) the walls should be faced with portland cement 1 inch thick, especially if untreated wood is to come in contact with the bricks.

USE OF CHEMICALLY TREATED WOOD FOR INTERIOR WOODWORK, FURNITURE, ETC.

In the Southern States, especially in the subtropics, in the more valuable permanent buildings the interior woodwork, furniture, etc., should be impregnated with preservatives, since nonsubterranean termites that attack wood directly are common in those regions. Zinc chloride and chlorinated naphthalene [5] are effective preservatives.

Wood-pulp or fiber products, such as the various wood-fiber processed or composition wall and insulating boards, for interior finish

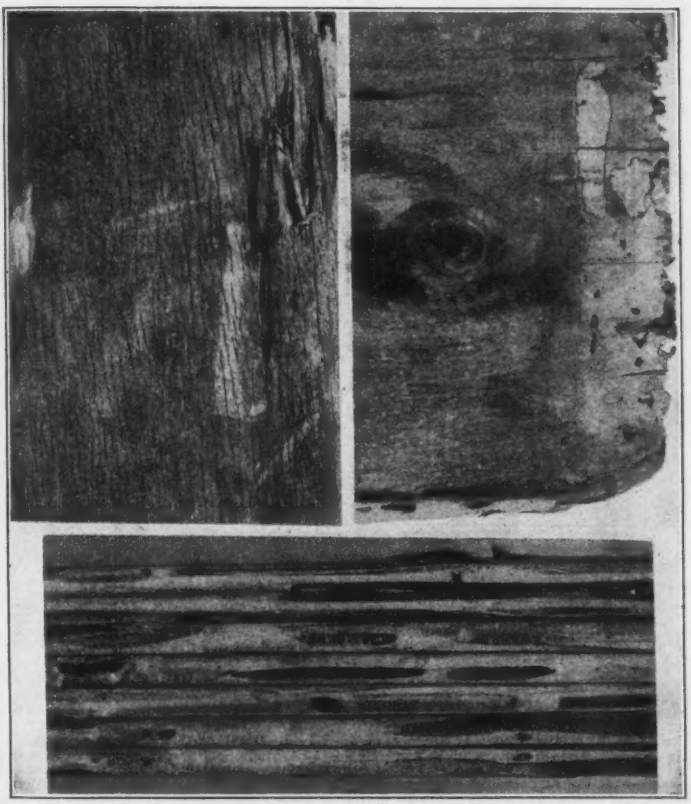

FIGURE 15.—The bottom of a bureau drawer, damaged by the nonsubterranean wood-boring termite *Cryptotermes brevis*, which occurs at Key West, Miami, and Palm Beach, Fla.

and substitutes for lath (fig. 18), or for exterior use, can be protected from attack by termites by adding certain poisons (such as coal-tar creosote at the rate of 2 gallons per 1,000 square feet) to the pulp or fiber laminated boards in the course of manufacture. Experiments with poisoning such products are not yet complete enough to warrant the giving out of definite general recommendations.

[5] This preservative is usually referred to as trichlornaphthalene and, as compared with other chemicals, it is really comparable to a technical product having naphthalene, monochloronaphthalene, dichlornaphthalene, and probably some of the higher chlorinations as impurities. Its melting point ranges between 190° and 210° F.—the specification under which it is sold.

CITY BUILDING CODES

Urban communities can do much to prevent termite damage by including in their building regulations or codes a few simple provisions which, if enforced, will protect houses from termites. Some cities now have such rules governing the construction of buildings, which have proved very helpful. The Bureau of Entomology will gladly supply information that will aid in drafting suitable regulations.

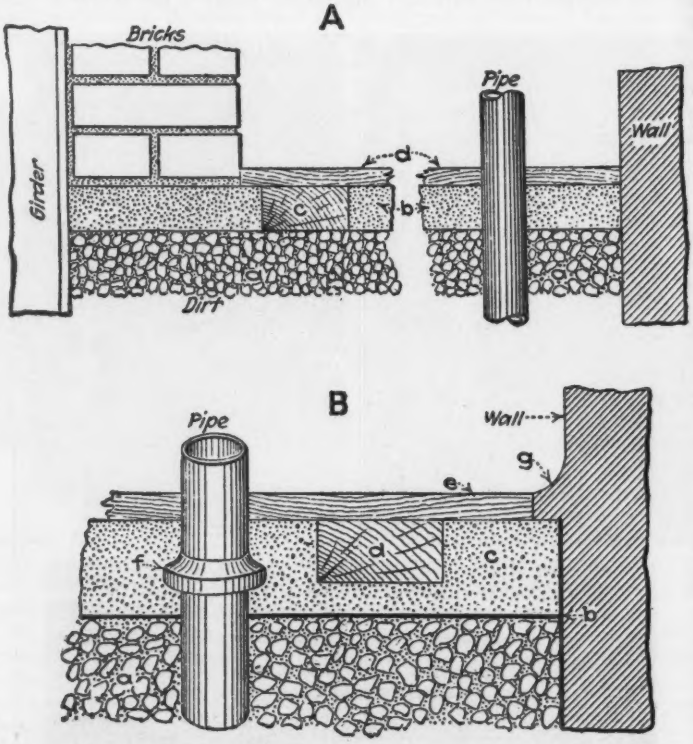

FIGURE 16.—*A*, Improperly constructed concrete flooring: *a*, Gravel or cinders loosely cemented with coarse concrete, 3 inches thick, but with many crevices and holes; *b*, solid, dense concrete, 2 inches thick; *c*, 2- by 4-inch untreated wood sleeper set in moist concrete over the grout; *d*, ⅞-inch pine flooring nailed to sleepers. *B*, Properly constructed concrete flooring: *a*, Gravel or cinders loosely cemented with coarse concrete, but with many crevices and holes; *b*, coal-tar pitch waterproofing ⅛ inch thick; *c*, dense concrete, 3 inches thick; *d*, 2- by 4-inch treated wood sleeper set in a groove in concrete which insulates it from termites in the earth; *e*, ⅞-inch flooring nailed on sleepers; *f*, metal collar around pipe which runs down through the concrete (this collar should be soldered to the pipe and embedded in the concrete); *g*, shoulder of concrete at point of wall and concrete floor to avoid a right-angle connection and consequent cracking.

The principal object is to keep all untreated wood from contact with the ground, where the termites live and from which they get their moisture. The regulations should, therefore, stipulate that no floors, sills, beams, clapboard, etc., of untreated wood may be laid on or in the earth and that untreated beams may not be laid in concrete without at least 1 inch of concrete underneath and separating it from the earth; that no lime mortar may be used in foundations or in cellar

walls where they are in contact with the earth, since termites are able to penetrate lime mortar [6] after some years' service; that all brickwork extending below the surface of the ground shall be faced and capped with concrete at least 1 inch thick; and, where nonsubterranean as well as subterranean termites occur, that only woodwork impregnated with preservatives be used for exterior and interior construction, unless it is impracticable to obtain such treated wood. Sun parlors, porches, steps, etc., in places where there is an earth fill, should be isolated from the main building. For further details see United States Department of Agriculture Leaflet 101, Injury to Buildings by Termites.

LOCATING AND TEMPORARILY ARRESTING THE DAMAGE

Although it may be difficult to eliminate termites and stop further damage by them, when once these insects have become established in

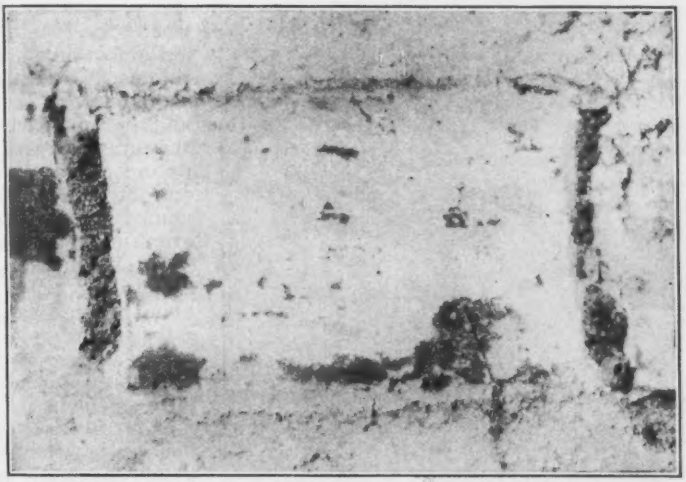

FIGURE 17.—Interior view of portion of whitewashed brick foundation wall of building, below ground level, showing shelter tubes of our common subterranean termite *Reticulitermes* sp., penetrating the disintegrated lime mortar. These termites came through the earth banked up against the exterior wall. To remedy this condition the exterior wall will have to be faced with concrete for some distance below the ground level.

the woodwork of a building, the approximate point of entrance should be sought at once by careful examination of all woodwork in contact with the ground. To do this, it may be necessary to tear up the foundations, flooring, and some other woodwork. The foundation timbers and interior woodwork found damaged should be removed, and the ground where they were set should be broken up and drenched with orthodichlorobenzine at the rate of 1 gallon per 10 linear feet, which will kill or at least temporarily prevent the further activity of termites at that point.

[6] The Bureau of Standards of the U.S. Department of Commerce recommends a mortar composed of 1 part portland cement to 3 parts of sand graded from fine to coarse, with no grains larger than will pass through a no. 10 sieve, to which may be added 10 percent by weight of the cement of some workability agent, such as hydrated lime, for use in locations where termites abound. Such a mortar, it is believed, will have the desirable properties of both cement and lime mortars and, furthermore, will contain a sufficient quantity of cement to prevent the penetration of it by the termites (fig. 17).

INDICATIONS OF INFESTATION

The emergence of large numbers of the flying termites is an indication as well as a warning that the woodwork is infested, and the point of emergence indicates the approximate location of the infested timbers. Large numbers of the dead winged adults or of the discarded wings will usually be found near infested timbers following swarming. Frass and earth thrown out of crevices through which the insects emerge are also evidences of their presence. The presence of branching shelter tubes of small diameter, made of earth mixed with finely powdered wood, on foundation timbers or other woodwork, or over the surface of stone, brick, or other impenetrable foundation material (fig. 13), through which the insects travel from the ground to the woodwork, is another aid in locating infestations. These tubes should be broken off and the ground where they originate broken up and drenched with one of the liquids named in the paragraph under the heading, Destruction of Breeding Places about the Building Site (p. 7).

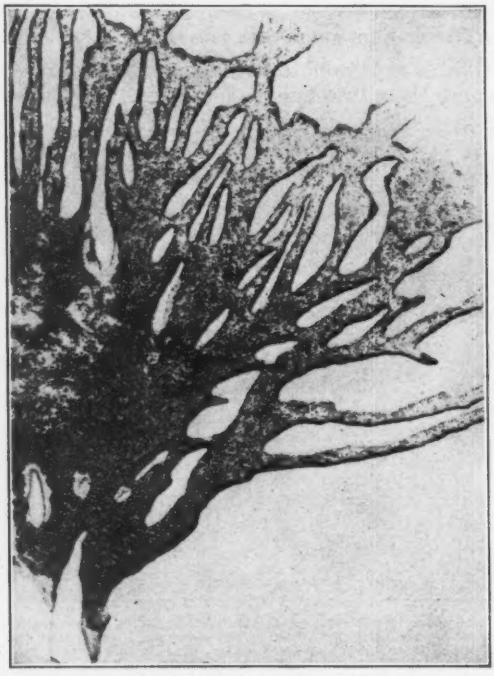

FIGURE 18.—Pressed wood-pulp tile mined by subterranean termites infesting the building, Biloxi, Miss.

In the case of the nonsubterranean termites, which infest wood directly, evidences that they are damaging wood are the impressed pellets of excrement (fig. 14) which are expelled from the wood. Other evidences are the holes, similar in size to BB shot, where the insects entered the wood (fig. 19).

KILLING THE WINGED ADULTS WILL NOT STOP THE DAMAGE

When efforts are made to prevent further damage by termites in buildings, it should be realized that the numbers of these insects may be constantly recruited from some undiscovered, outside, central colony. The destruction of the winged colonizing adults at the time of emergence, although beneficial in preventing the establishment of new colonies, out of doors, will not eradicate the insects infesting the woodwork. These winged adults are harmless indoors and will soon

die. Sweeping them up with a vacuum cleaner is a simple method of getting rid of them. The most destructive forms are the white, wingless workers, which remain within the wood.

DISCONNECTING WOOD FROM THE GROUND

Subterranean termites infesting beams or other wood will die if the wood is disconnected from the ground. Knowledge of this fact will save time and expense, especially in the case of old frame buildings, where extensive repairs would be unwarranted. Disconnecting untreated foundation timbers from contact with the soil will also cause the death of subterranean termites in the other woodwork, furniture, and stored material in the building, even if they have penetrated to the second or third floors. These timbers need not be removed or replaced unless seriously weakened structurally. However, if the wood is kept moist by some other means, such as water leakage, the termites will continue to work and thrive. This applies especially to damp corners of basements near outside water pipes, bathrooms, kitchens, and the like.

FIGURE 19.—Entrance holes of sexual, colonizing adults of a nonsubterranean termite (*Kalotermes hubbardi*) in wood of dead cottonwood tree in Arizona.

REPLACING WOOD WITH CONCRETE

Concrete floors and concrete baseboards should be substituted for wood. Untreated beams penetrating through concrete floors into the earth and the lower parts of door jambs and casings should be cut off at least 6 inches above the ground or floor and replaced with cement plinths, which should project one quarter inch beyond the jambs and casings. Metal strips should be sunk down from the woodwork into the concrete. Wooden thresholds, wainscoting, window sills, subsills, and stools in the basement or ground floor should be removed and placed on concrete (a layer of concrete between the earth and wood (fig. 16, *B*)) or replaced with concrete.

REPLACING WOOD WITH METAL

In basements and cellars steel rails or other structural metal work can sometimes be economically used to replace weakened timbers.

COMBATING TERMITES THAT ARE NONSUBTERRANEAN IN HABIT

Unlike the subterranean termites, nonsubterranean termites do not live in the soil, but fly to and attack wood directly. To combat such termites it is advisable to remove and replace the wood if the

damage is slight and localized. Where the wood has been seriously damaged, but not structurally weakened, saturate the infested wood with orthodichlorobenzene. The wood should be thoroughly saturated with this chemical, a rag or mop being used, dripping wet, or the liquid can be applied as a spray. Several applications may be necessary to kill the insects.

If orthodichlorobenzene is used as a spray, it is advised that the house be opened up before and for some time after treatment, since there is quite an odor to the chemical which may prove disagreeable in a closed room. Also, in spraying timbers overhead care should be taken not to let the liquid drip down, since it might slightly burn the face and hands and would be painful if it got into the eyes.

If the orthodichlorobenzene treatment is not practicable and the wood is too thick for the solution to penetrate, blow dry paris green, or the less dangerous although less effective sodium fluosilicate, by means of a bellows into holes bored with an auger into the infested wood; these holes should penetrate to the galleries of the termites. If, because of moisture, the powder becomes caked, the treatment should be repeated. Wood structurally weakened should be removed and replaced with chemically-treated wood or strengthened with structural steel.

By far the greater and more serious damage to timber in the United States is caused by termites of the subterranean type. Department of Agriculture Leaflet 101, on the prevention of damage by termites in buildings, discusses in detail the control of subterranean termites infesting buildings.

PREVENTING AND REMEDYING INJURY TO LIVING VEGETATION

FRUIT, NUT, SHADE, AND FOREST TREES

Termites cause occasional but serious injury to individual living trees, shrubs, nursery stock, and grapevines. In case of shade trees the infestation may start as local at the base and extend more generally through the heart wood. A wise preventive measure is the removal of all loose wood which may afford them shelter, such as prunings, dead and dying trees, and the like, and untreated fence posts and similar material.

Termites are also occasionally a pest in orchards, not only in new orchards planted on freshly cleared land where there is such debris, but also, because of neglect, in old orchards, in both Florida and California.

Cleanliness in orchard and forest management is important. Since termites in the Southern States render unmerchantable the forest trees that have been killed by insects, fire, or disease, all timber from such trees should be utilized or removed as promptly as possible in areas where termites are common.

In the case of the pecan it is recommended that 2 or 3 cereal crops be grown on newly cleared land before the young trees are set out.

TREE SURGERY

Properly executed tree surgery sometimes is effective in repairing injury by termites to valuable old fruit and shade trees. The termite-infested wood should be carefully cut out, and the dead heartwood should be given a brush treatment with coal-tar creosote. This

treatment should not extend to within an inch of the living sapwood. Then the cavity should be filled with a suitable material.

COVERING SCARS AND PRUNED AREAS

To prevent infestation, care should be taken that the trees do not become scarred, especially near the base. Scars and all pruned areas should be treated with a mixture of one fourth creosote and three fourths coal tar. This mixture should not be allowed to come in contact with the living tissues at the edges of the bark; to protect them a shellac should be applied.

COMMERCIAL FERTILIZERS

Soil heavily manured will attract subterranean termites, since they can obtain food from the animal manure; commercial fertilizers should be used in preference in regions where termites are common in the soil.

YOUNG PLANTATIONS OR NURSERY STOCK

Injury to nursery stock from 1 to 3 years old will be more serious on recently cleared land and where decaying wood is abundant. Any debris in which the insects breed should be removed. In general the use of recently cleared land should be avoided in planting nursery stock. Earth used in banking should be free from rotten wood. Care should be taken not to allow the roots to dry out before being planted, as weakened stock is specially susceptible to attack; particular care should be given grafted stock.

INSECTICIDES

When valuable trees are infested but not yet dying, subterranean termites can be killed in the soil, if it is moist and not too compact, by breaking it up near the tree and pouring carbon disulphide on the earth at a distance of about a foot from the trunk, then covering the liquid over with earth. The gas from this liquid will penetrate the subterranean galleries of the termites. It is somewhat dangerous to plant life, and very large doses should not be used. *Care should be taken in handling this volatile fluid, as the gas or vapor from it is highly inflammable and explosive when mixed with air in certain proportions; no flame should be brought near it, and the fumes should not be inhaled, as they are poisonous.* There are indications that an emulsion of carbon disulphide, which is on the market ready for use, may prove more effective than carbon disulphide alone; as in the case of the disulphide itself, the earth is loosened up and the emulsion poured on, at least a foot from the tree. Carbon tetrachloride,[7] the gas from which is neither explosive nor inflammable, can be similarly used but is apparently not so effective as carbon disulphide. The gases from carbon disulphide and carbon tetrachloride, being heavier than air, will not readily rise.

Where nonsubterranean termites are infesting living trees, they can be poisoned with dry paris green in the manner discussed on page 18.

[7] Carbon tetrachloride is a thin, transparent, colorless, volatile liquid, which forms a gas with a pungent, aromatic odor. Like carbon disulphide, it is heavier than air. Although it is only about one half or one third as effective as carbon disulphide when used at the same dosage rate, it has the great advantage that its gas is neither explosive nor inflammable; there will be no fire risk attending its use in buildings.

VINEYARDS

In vineyards all dead or diseased vines should be removed. All exposed areas left by pruning should be painted with preservative coatings, and the prunings should be burned promptly. Nearby stands of tree windbreaks should be carefully cared for and kept free from infestation by termites. Trellis posts should be creosoted.

FIELD AND TRUCK CROPS

DEEP FALL PLOWING

Deep, late, fall plowing will be of value in breaking up the galleries and nests of subterranean termites on ground planted to field or truck crops. Irrigating the land, where practicable, will be effective; this can be done before planting the crop.

BURNING STUBBLE

Care should be taken not to plow under stubble which will serve as food for termites; it should be burned. The use of commercial fertilizers instead of animal manure is also recommended where subterranean termites are common in the soil.

ROTATION OF CROPS

As a result of the frequent stirring of the soil, rotation of crops will aid in preventing termites from injuring them. Plowing and fallowing are more practical than the use of insecticides in preparing the soil to prevent termite damage.

FLOWERS AND GREENHOUSE STOCK

Termites injure a great variety of flowers in gardens, as well as many plants grown under glass in greenhouses, where the warm, moist atmosphere maintained throughout the year promotes greatly the activity of the insects. Injury from termites is especially common where the plants are perennial and have woody stalks.

SOURCES OF INFESTATION

Heavily manured flower beds are a source of infestation to the stems of the flowers, as well as to the woodwork of buildings near by, if suitable protection is lacking. Termites can obtain food from the animal manure. Untreated wooden stakes used as supports of plants often become infested, and in time the insects attack the plants. Where greenhouses have already been built and termite damage is due to poor construction termites often attack old label sticks, the wooden uprights supporting wooden benches set on or in the ground, and the wooden bench bottoms and plant pots, and later attack the growing plants. The insects come up through the ground and form dirt galleries over the supports, or burrow up through the wooden bench legs and run galleries the full length of the benches. They enter the soil in the pots through the drainage holes and eat out the main stalk of the root, killing the plant very quickly.

PROPER CONSTRUCTION OF GREENHOUSES

Proper construction of greenhouses will practically safeguard plants growing in them from all injury by termites. Iron frames and concrete work should, wherever possible, replace bricks or woodwork.

In cases of infestation of old greenhouses, all wooden uprights supporting wooden plant benches should be sawed off, if set on or in the ground, and rested on stone, bricks, or concrete, above the surface of the ground. Proper repairing, including the removal of all infested wood, will prevent the plants from becoming infested in turn. Where woodwork is necessary the wood should be impregnated with zinc chloride or bichloride of mercury; it can be painted after treatment. Wood impregnated with coal-tar creosote cannot be used with safety in greenhouses.

AVOIDING STABLE MANURE

In flower gardens, especially those located near the woodwork of buildings, commercial fertilizer should be substituted for stable manure in order to protect not only the buildings but also the growing plants.

INSECTICIDES

Either carbon disulphide or carbon tetrachloride [8] can be used to kill termites in the soil if it is moist and not compact. These gases should not be used too near the infested plants, or the plants should be removed temporarily until the soil has been treated. Small holes should be made near the infested plants and a small quantity of the liquid chosen poured in and the holes immediately closed tightly with earth. Calcium cyanide [9] has also been found effective, but it should not be placed near living plants; it mixes readily with and enriches the soil and gives off an insecticidal gas which *should not be inhaled, as it is poisonous.*

An effective control may be found in the use of kerosene nicotine oleate or a 5-percent kerosene emulsion.[10] If the greenhouse benches are infested, but for any reason cannot be replaced, they should be soaked thoroughly with this emulsion, as should also the ashes and sand under the pots on the benches. This may be done by removing the potted plants from a section of the bench, spraying that section, and moving the pots on the bench to cover the treated area, thus giving access to another section. Potted heliotropes and geraniums have been treated directly with the 5-percent kerosene emulsion without injury to the plants, and the white ants in the soil of the pots were all killed. The soil should be wet down before this spray is used. This treatment should be given late in the afternoon and be followed early the next morning with a thorough syringing of the soil with water to wash out the surplus oil. It is important to remove all infested pots from the bench as soon as the infestation is noticed and to destroy the termites with kerosene emulsion.

[8] See footnote 7 (p. 19).

[9] 2 ounces of calcium cyanide to 1 square yard of ground is recommended.

[10] Kerosene emulsion is made as follows: Kerosene, 2 gallons; fish-oil soap, ½ pound; water, 1 gallon. Dissolve the soap in hot water and pour in the oil slowly, with constant stirring to emulsify. Dilution: If 37 gallons of water be added to the above stock emulsion it will give 40 gallons of 5-percent kerosene emulsion.

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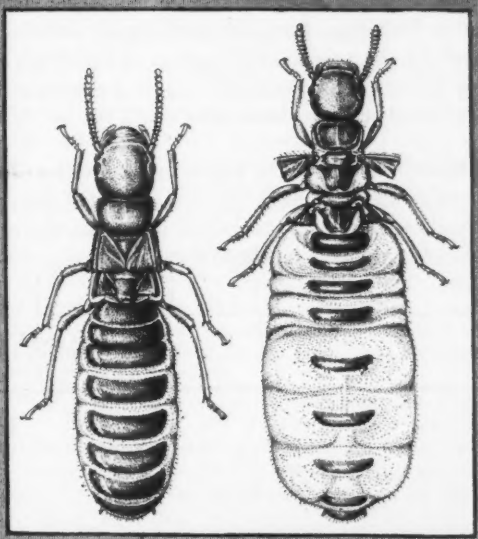
PREVENTING DAMAGE BY TERMITES OR WHITE ANTS



THROUGHOUT the United States, but especially in the Southern, Central, Southwestern, and Pacific Coast States, native termites, or white ants, cause serious damage to the foundations and woodwork of buildings and articles in the buildings, and to living trees, crops, and other vegetation. Damage to buildings, furniture, and similar articles can be prevented by the proper construction of buildings and the chemical treatment of wood, and injury to growing vegetation can be reduced by clean culture and the use of insecticides.

This bulletin describes the habits and activities of subterranean and nonsubterranean termites and sets forth in detail the precautions to be taken against them and the remedies available when damage has been done.

Washington, D.C.

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PREVENTING DAMAGE BY TERMITES OR WHITE ANTS

By T. E. SNYDER, *senior entomologist, Division of Forest Insect Investigations, Bureau of Entomology and Plant Quarantine*

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TERMITES AND THEIR HABITS

DISTRIBUTION AND FORMS

THE TERMITES or "white ants", in this country are mostly destructive native insects. Fifty-eight species of them occur in the United States. They are distributed throughout the country, although in the southern, southwestern, and Pacific coast regions, where both the subterranean and nonsubterranean kinds occur (fig. 1), they are more numerous and injurious than elsewhere.

These so-called "white" ants are not true ants, although they look like ants and live in colonies made up of different forms or castes. In these nests or colonies both wingless and winged mature individuals are produced. The brownish or blackish, elongate, slender, antlike, colonizing, sexual adults (fig. 2) with long white wings, unlike the other forms, have functional eyes, and their bodies are able to endure full sunlight. These migratory males and females appear normally once a year during a short period.

There are three stages in the life of termites—the egg, the nymph, and the adult. The adults are of two kinds—sterile and fertile. The sterile adults of our common subterranean termites and of many other species include two forms (or castes)—the soldiers (fig. 3, *a*) and the workers (fig. 3, *b*); and the fertile or sexual adults include three normal forms (fig. 4, *F* to *K*).

LOCATION OF COLONIES OR NESTS

The nests of some species of termites [1] are in the earth and in dead and decaying wood. These more common and injurious species are of subterranean habit, timber and trees being attacked by the workers only through the ground. The nests of some other less common species,[2] however, are excavated in wood and trees by the winged forms, there being no workers and no underground life.

[1] Genera *Reticulitermes* Holmgren, *Heterotermes* Froggatt, *Amitermes* Silvestri, etc.
[2] Genera *Termopsis* Heer, *Kalotermes* Hagen, *Neotermes* Holmgren, *Cryptotermes* Banks, etc.

With the clearing of land and the consequent destruction of their natural breeding places in the dead trees, decaying stumps, and logs of the forests, termites become increasingly destructive to the woodwork and contents of buildings (figs. 5–11), telephone poles, fences, or any timber in contact with the ground, as well as to living vegetation, including not only fruit and shade trees, shrubs, and flowers, but also truck (fig. 12) and field crops and, in California, grapevines. The principal food of termites is cellulose, which they obtain from either dead or living vegetation.

Termites in the United States are mainly species of subterranean or wood-boring habit and are not so spectacular or common as the mound-making or tree-nesting termites of the Tropics. Very few termites in this country have habits that make them conspicuous, or come above ground into the sunlight except during the annual coloniz-

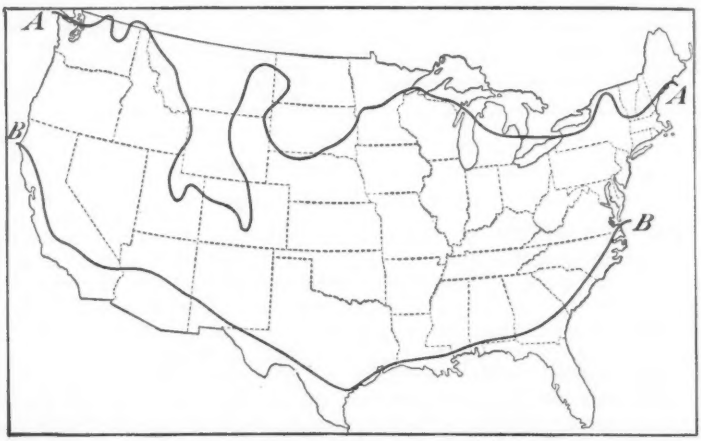

FIGURE 1.—Map showing (line *A–A*) the northern limit of damage done by subterranean termites in the United States and (line *B–B*) the northern limit of damage done by dry-wood or nonsubterranean termites.

ing swarm; hence they largely escape notice until they become injurious.

TERMITES THAT ARE SUBTERRANEAN IN HABIT

Subterranean termites live in forests, building their nests in the wood of standing timber, logs, or stumps; in cleared land, in any wood in contact with the ground; or, in the plains, in a labyrinth of underground passages in the earth, usually underneath wood or vegetation.

Termites are soft-bodied and always conceal themselves within wood, in the earth, or within their earthlike carton shelter tubes (fig. 13). The grayish-white, soft-bodied, wingless, sterile "workers" (fig. 3, *b*) are in reality the destructive form. These workers make the excavations occupied by the colony and enlarge and extend them as the colony increases. They live underground or within the wood, are blind, and shun the light; as a result they are rarely seen. In burrowing through wood the workers often completely honeycomb it, usually following the grain and eating out the softer, thin-walled,

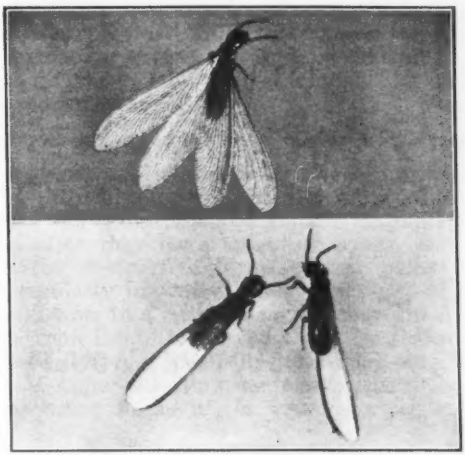

FIGURE 2.—Winged sexual adults of eastern subterranean termites; upper, *Reticulitermes flavipes*, nearly three and one-half times natural size; lower, *R. virginicus*, three times natural size.

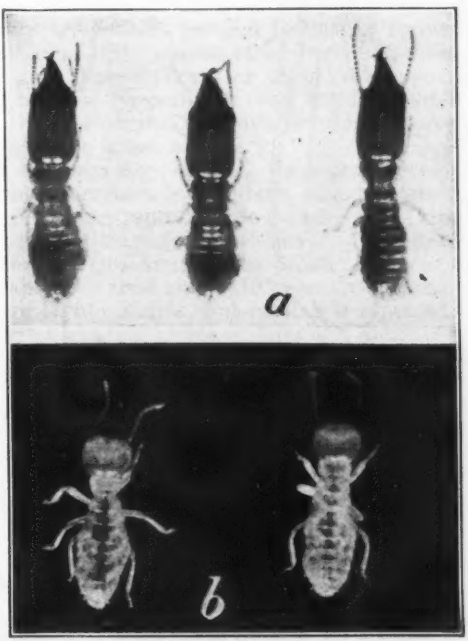

FIGURE 3.—Mature soldiers (*a*) and mature workers (*b*) of the eastern subterranean termite *Reticulitermes flavipes*. Slightly more than six times natural size.

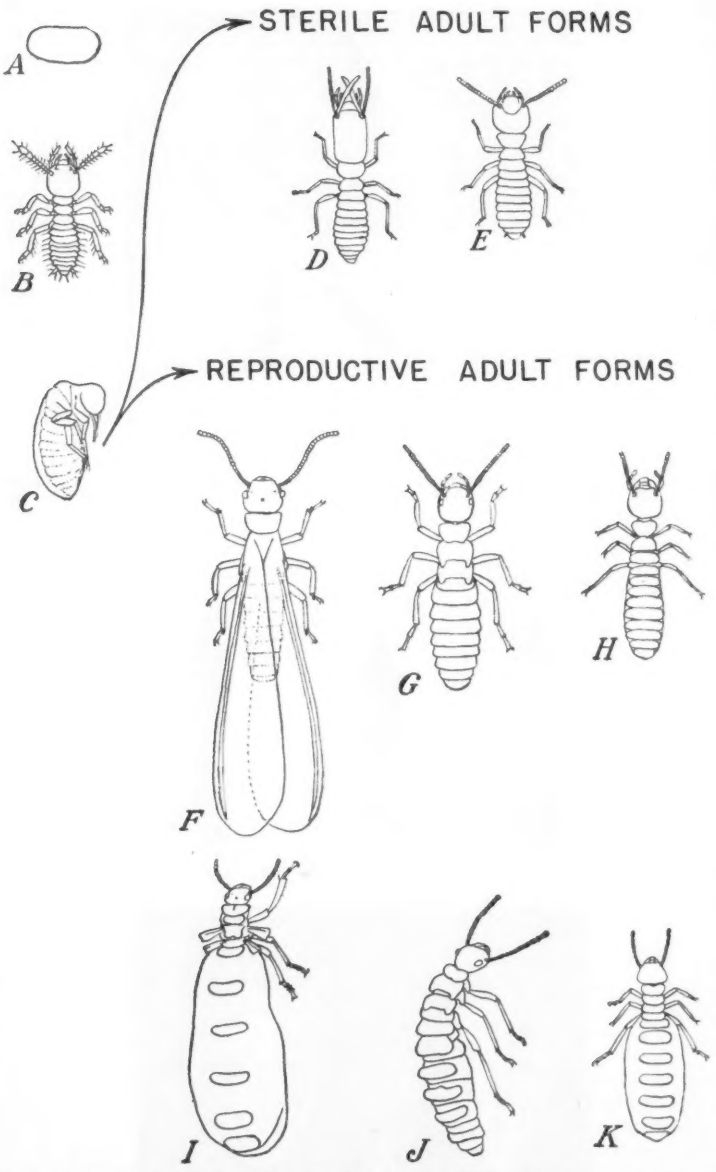

FIGURE 4.—Diagram showing the relationships of the stages and forms of our common subterranean termite *Reticulitermes, flavipes: A*, Egg; *B*, recently hatched nymph; *C*, immature nymph in quiescent or resting stage; *D*, soldier; *E*, worker; *F*, sexual winged adult; *G*, sexual adult with wing pads; *H*, workerlike wingless sexual adult; *I*, *J*, and *K*, enlarged egg-laying females or queens, corresponding to *F*, *G*, and *H*, respectively. *D* and *E* are sterile adult forms; *F*, *G*, *H*, *I*, *J*, and *K* are fertile or reproductive adult forms. (The enlargements are approximately as follows: *A*, ×16; *B*, ×13½; *C*, ×10; *D*, ×4½; *E*, ×5½; *F*, ×6; *G*, ×4½; *H*, ×5; *I*, ×2½; *J*, ×2½; *K*, ×3.)

larger-celled spring or new wood. They are able to penetrate the hardest of woods, provided they have access to moisture in the ground. In extending their galleries in wood and vegetation, subterranean species carry moisture with them by means of moist excrement mixed with earth.

TERMITES THAT ARE NONSUBTERRANEAN IN HABIT

The nonsubterranean termites which are injurious attack wood directly; but, instead of following the grain continuously, they excavate through it longitudinal chambers of limited length. The sexual adults, after they have lost their wings, and the young or nymphs, are the destructive forms. Their pellets of excrement (fig. 14) are regularly impressed, and sometimes completely fill or block up the burrows in a compact mass; they are often expelled as dry droppings from the infested wood. These termites are destructive to the woodwork and furniture in buildings (fig. 15), as well as to living trees. Apparently they can exist without the great amount of moisture necessary to the life of termites which are subterranean in habit.

THE COLONIZING SWARM

At certain seasons, usually spring or fall, but varying with the species and the locality, the winged, sexual individuals migrate in large numbers from the parent nests. They then lose their wings and breed new colonies. In the case of the subterranean termites, wood and trees are usually entered indirectly through the ground, although sometimes these insects enter trees under bark loosened by sunburn, etc., or through scars or borer holes, provided sufficient moisture is present. Nonsubterranean termites enter the wood directly, or, in the case of trees, through wounds or borer holes or under loose bark; moisture is not necessary.

In the new quarters eggs are laid, the young develop, and in a few years the colony increases in numbers, and the workers are able to feed and care for the reproductive forms—the "king" (title page, left) and "queen" (title page, right)—as well as the soldiers (fig 3, *a*), which are sterile forms adapted to protect the colony from insect enemies, notably the true ants. In recently formed young colonies the rate of egg laying is slow, but mating is repeated, and, although there is at first a gradual increase, later the increase in the numbers of the broods is rapid. In old colonies there are thousands and tens of thousands of individuals.

Egg laying occurs over a considerable period during the warm months in colonies out of doors. In infested buildings artificially heated, where an even temperature is maintained, the insects are active and may lay eggs every month of the year. The number of eggs laid depends on the age of the queen.

THE REPRODUCTIVE FORMS

Owing to the increasing number of eggs that develop within her the queen becomes enlarged, but never loses the power of locomotion. It was once believed that, since the queen mother was the source of the colony life, the termite colony would be exterminated if she were destroyed, but this has been disproved by more recent studies. In addition to the forms that have shed their wings, several different types of reproductive forms occur—forms with wing pads (the undeveloped wings of the nymphs) and wingless reproductive adults.

The winged forms, however, are the normal type and occur as a single pair, whereas there may be hundreds of the other forms heading colonies. The reproductive forms with wing pads and the wholly wingless type usually have little color in the body, and the eyes are

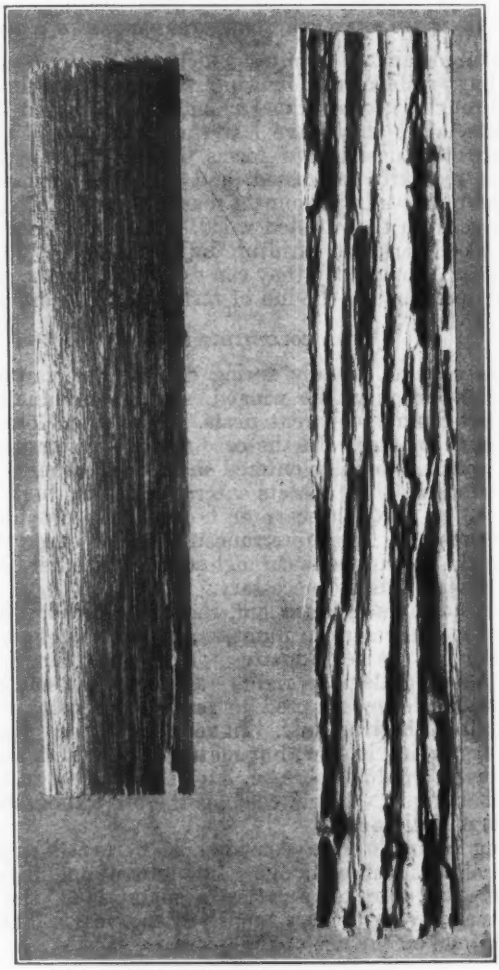

FIGURE 5.—Damage to oak flooring done by the common eastern subterranean termite *Reticulitermes flavipes*. Note that damage is not apparent on the upper surface.

small. These forms rarely come aboveground or leave the burrows in wood.

The location of the queens in the colony depends upon the season of the year. During periods of intense heat or drought in the Plains or in arid or prairie regions the subterranean termites burrow deeply below ground or to a less depth under stones, cow chips, etc. During the winter in the colder climates they burrow below the frost line.

Whole colonies of subterranean termites migrate when conditions become unfavorable. The nonsubterranean termites, on the other

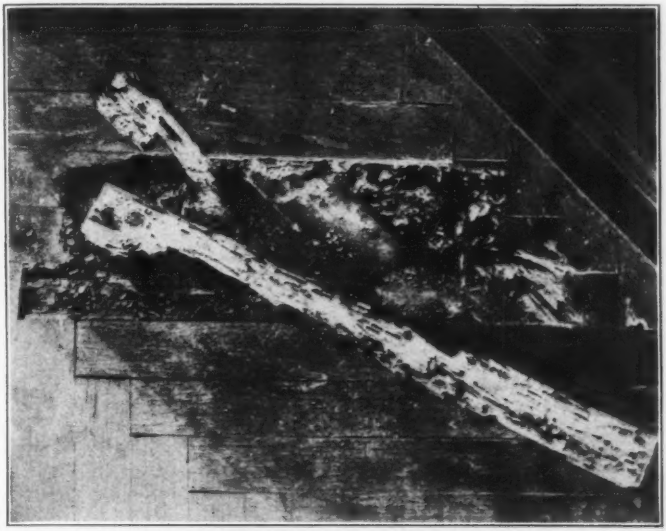

FIGURE 6.—Quartered-oak flooring damaged by the subterranean termite *Reticulitermes flavipes* in an infested building, Washington, D.C., 1915.

hand, are not able to leave the wood in which they have excavated their nests.

PREVENTING AND REMEDYING DAMAGE TO WOODWORK OF BUILDINGS

DESTRUCTION OF BREEDING PLACES ABOUT THE BUILDING SITE

If buildings are to be constructed on recently cleared woodland, decaying logs and stumps should be removed from the soil in the vicinity and burned. If, because of the presence of decaying wood and humus, the subterranean termites are numerous in the earth, the soil should be deeply plowed or otherwise broken up and treated with chemicals to kill the insects. Effective poisons for this purpose are a 10-percent solution of sodium arsenite;[3] 1 part coal-tar creosote and 3 parts kerosene oil (this mixture should be strained through burlap before

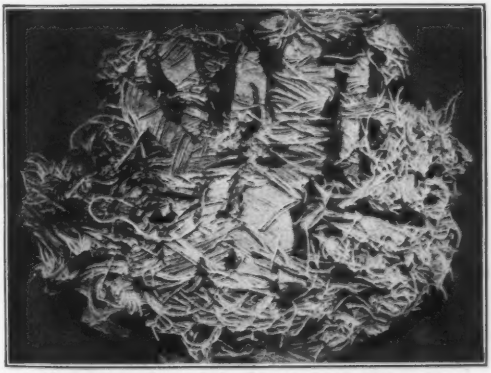

FIGURE 7.—Tube of coarse yarn from bale of cotton on floor of building infested by subterranean termites, Greenville, S.C.

[3] This poison is caustic and should not be used near living vegetation.

being used); carbon disulphide emulsion, which is on the market ready for use; orthodichlorobenzene (50 gallons per 1,000 square feet). Live steam forced into the soil will serve the same purpose as the gases. Decaying fence posts, sidewalks, etc., should be removed and replaced with treated wood, concrete, stone, or other resistant substances; such decaying material would facilitate the formation or perpetuation of the termite colonies.

PROPER CONSTRUCTION OF BUILDINGS

Termites will infest not only old buildings but also improperly constructed new buildings, and these are often badly infested. It is not the age of the building but the manner in which it has been constructed that renders it liable to attack.

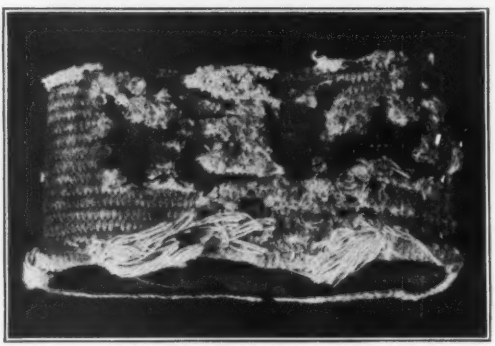

FIGURE 8.—Cotton jacket of rubber-lined fire hose from infested building in Missouri, damaged by subterranean termites (*Reticulitermes* sp.).

INSULATION

Complete insulation from the ground of all untreated woodwork of buildings is the only effective permanent remedy against attack by subterranean termites, and the only relief from their presence. These insects must maintain contact with the ground to obtain the moisture necessary for their existence. When contact with their moisture supply in the earth is cut off, the subterranean insects in the damaged wood, no matter how numerous, soon die.

FOUNDATIONS, SUPPORTS, ETC.

To prevent subterranean termites from reaching the woodwork of buildings from their nests in the ground, the foundations of buildings should be constructed, if possible, entirely of stone, brick, concrete, or concrete and steel,[4] including the pillars in the basement or cellar. The walls, partitions, and flooring in the ground floor, basement, or cellar should also be of concrete. Wooden flooring can be laid over this concrete floor if desired. If the flooring is to be of concrete, the concrete should be laid on a gravel base.

In buildings where stone, brick, or concrete foundations are impracticable, timber impregnated with coal-tar creosote should be employed, and no untreated wood should come in contact with ground which may be infested with termites. Wood to be protected from termites should be impregnated with coal-tar creosote by either the cylinder-pressure or the open-tank process. Full details regarding

[4] In the Southern States, especially in the subtropics, the more valuable permanent buildings should be constructed entirely of steel and concrete.

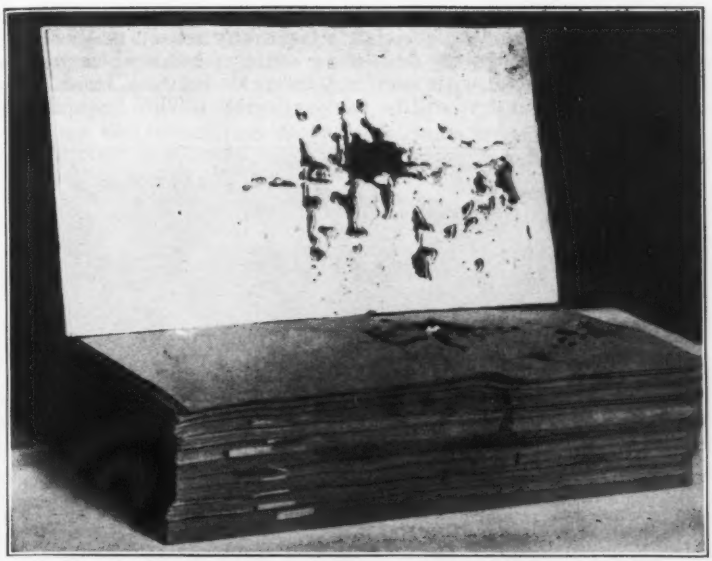

FIGURE 9.—Revenue stamps damaged by the subterranean termite *Reticulitermes flavipes* on infested flooring in the Bureau of Engraving and Printing, Washington, D.C., 1921.

FIGURE 10.—Correspondence and advertisement regarding issue of county bonds; damaged by subterranean termites infesting the building in Virginia in which they were stored.

these processes can be obtained from the United States Forest Products Laboratory, Madison, Wis. The open-tank process is simpler, can be made to give satisfactory results where properly used, and can be operated by unskilled labor. If for any reason neither of the foregoing processes can be used, three coats of hot coal-tar creosote brushed on the wood, with sufficient intervals between brushings to permit each coat to dry, will be fairly effective. This method, however, is not generally recommended, since it will preserve the wood for only a few years.

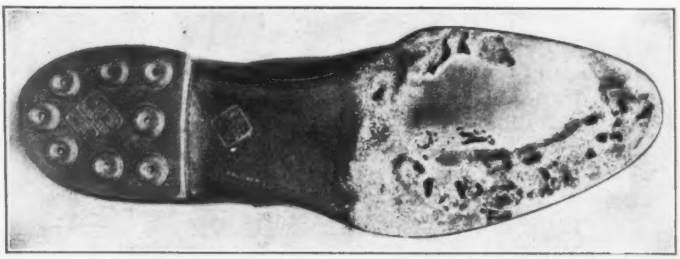

FIGURE 11.—Damage done by the subterranean termite *Reticulitermes flavipes* to shoe stored on infested woodwork in a building in New York City.

The supports of porches or steps should never be laid directly on the ground, but should rest on rock or concrete. Window sills and frames in the basement or cellar should be laid over concrete and the woodwork should not come in contact with the ground. The supports of the woodwork of coal bins in basements or cellars should not be set in the ground, but should rest on concrete, not extending through the concrete into the soil.

FIGURE 12.—Injury to carrots caused by the subterranean termite *Reticulitermes claripennis*, at Dallas, Tex.

CONCRETE FLOORING

Even in permanent stone or concrete and steel buildings the concrete flooring is often constructed improperly. Usually the base of the concrete floor is a loose combination of coarse gravel or cinders and cement grout. This very rough conglomerate, even if several inches thick, has many cracks and large holes running through it. Over this is laid a layer of solid concrete about 2 or 3 inches thick, of fine texture, in which untreated wooden sleepers are laid while it is still moist. These sleepers nearly or quite reach the coarse, open

conglomerate in contact with the earth, and to them is nailed the wooden flooring (fig. 16, *A*).

It will be seen that this is faulty construction. Termites have free access from the earth, in which they have galleries, through the porous conglomerate, to the untreated beams and flooring. *There should be a layer of solid concrete at least 1 inch thick between the grout and the wood* (fig. 16, *B*).

Among the commonest means of infestation are wooden sleepers or stringers laid in concrete while the latter is still soft, or placed before

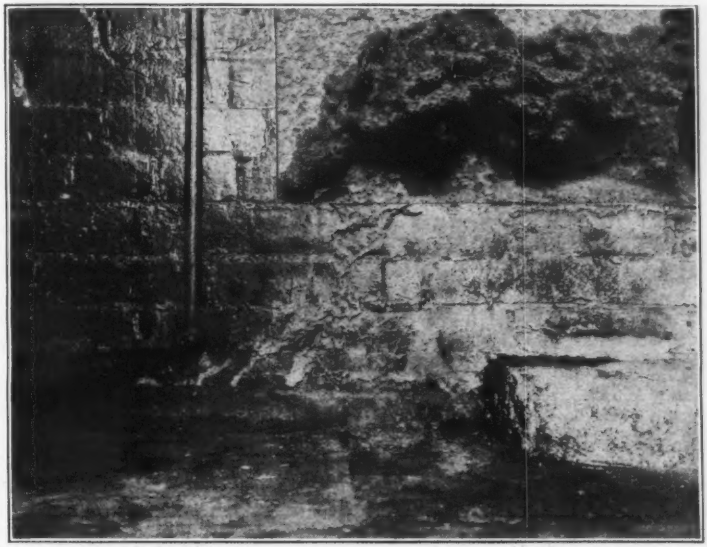

FIGURE 13.—Carton, earthlike, shelter tubes constructed by the eastern subterranean termite *Reticulitermes flavipes* over brick wall in dark, heated, damp basement; these tubes are used in passing over impenetrable substances. Inset, near view of tubes showing texture.

the concrete has been poured in. Termites enter through these wooden beams. Other common means of infestation are supports of coal bins extending through concrete and through the disintegrated lime mortar of brick walls.

TERMITE SHIELDS, GUARDS, OR METAL CAPS

Subterranean termites require constant access to soil moisture in order to attack wood. This requirement is supplied when wood is either in contact with the soil or when the termites can reach it through covered, earthlike shelter tubes. These shelter tubes may be constructed over the face of stone, concrete, or brick foundations and along water pipes or similar structures. In consequence they can be kept out of buildings by means of metal barriers. By firmly inserting a sheet of galvanized iron or "termite shield" in the surface of the masonry and letting it project horizontally for 2 inches, then turning the projecting part downward at an angle, communication of termites with the soil, where they obtain moisture, can be cut off. In

less pretentious frame buildings, metal caps should be placed over the tops of all construction stone piling or pillars.

This method is similar to that used in rat-proofing corncribs. It is effective and practicable where untreated timber is placed over masonry foundations.

Again, in the case of stone and steel buildings, the steel or stone pillars or piping extending down through the concrete floor to foundations in the earth often make infestation possible, owing to the fact that the concrete floor does not fit tightly about them. Overlapping strips of metal extending horizontally several inches from the pillars or pipes should be imbedded in the concrete floor in order to obtain a tight joint (fig. 16, *B*); or coal-tar pitch should be poured in to plug up the crevice or frame.

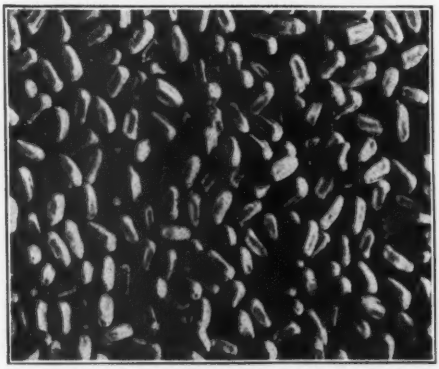

FIGURE 14.—Impressed pellets of excrement of nonsubterranean termites (*Kalotermes* sp.), which drop from infested wood. Greatly enlarged.

AVOIDING DAMPNESS

Dry foundation timbers and basement walls and flooring are important aids in rendering buildings safe from attack by termites. Dampness, warmth, and darkness are favorable to these insects. Concrete floors should be laid on a gravel base, which will prevent dampness and cracking. The points of juncture between concrete walls and wooden flooring should be filled in by rounding off the concrete at these places, since cracks often occur where the wall and floor join at right angles (fig. 16, *B*). Termites often come up through cracks between walls and flooring.

By mixing a heavy mineral residual oil with portland cement, a material is formed almost perfectly nonabsorbent of water and therefore excellent for use in damp-proof construction. Where the various patent or noiseless floorings are used on the ground floor they should always be laid over a concrete base, especially if they contain wood fiber as a constituent.

In no case should untreated beams be completely surrounded with mortar or brick; there should be a space around them sufficient to permit air circulation. Beams should not be set in earth or in moist concrete, but on rock or dry concrete, or in grooves in the latter.

Bungalows or frame buildings which have no cellar should be raised from the ground on stone, concrete, or brick foundations to a height which will allow light and air to penetrate beneath.

LIME MORTAR

Lime mortar sometimes disintegrates after a few years, and termites penetrate through the spaces thus left between the bricks, tiles, etc. Where lime mortar is used below the ground level (fig. 17) the walls should be faced with portland cement 1 inch thick, especially if untreated wood is to come in contact with the bricks.

USE OF CHEMICALLY TREATED WOOD FOR INTERIOR WOODWORK, FURNITURE, ETC.

In the Southern States, especially in the subtropics, in the more valuable permanent buildings the interior woodwork, furniture, etc., should be impregnated with preservatives, since nonsubterranean termites that attack wood directly are common in those regions. Zinc chloride and chlorinated naphthalene [5] are effective preservatives.

Wood-pulp or fiber products, such as the various wood-fiber processed or composition wall and insulating boards, for interior finish

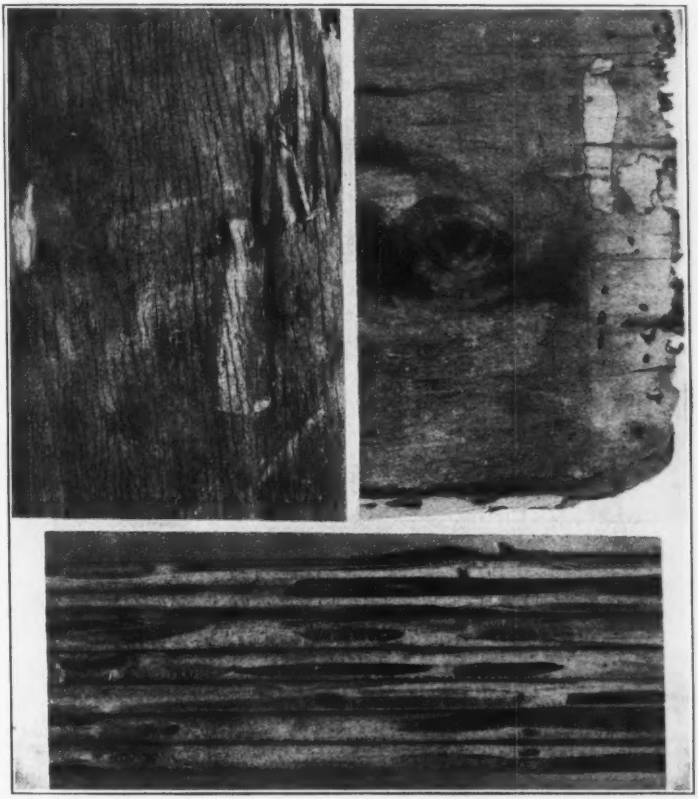

FIGURE 15.—The bottom of a bureau drawer, damaged by the nonsubterranean wood-boring termite *Cryptotermes brevis*, which occurs at Key West, Miami, and Palm Beach, Fla.

and substitutes for lath (fig. 18), or for exterior use, can be protected from attack by termites by adding certain poisons (such as coal-tar creosote at the rate of 2 gallons per 1,000 square feet) to the pulp or fiber laminated boards in the course of manufacture. Experiments with poisoning such products are not yet complete enough to warrant the giving out of definite general recommendations.

[5] This preservative is usually referred to as trichlornaphthalene and, as compared with other chemicals, it is really comparable to a technical product having naphthalene, monochloronaphthalene, dichlornaphthalene, and probably some of the higher chlorinations as impurities. Its melting point ranges between 190° and 210° F.—the specification under which it is sold.

CITY BUILDING CODES

Urban communities can do much to prevent termite damage by including in their building regulations or codes a few simple provisions which, if enforced, will protect houses from termites. Some cities now have such rules governing the construction of buildings, which have proved very helpful. The Bureau of Entomology will gladly supply information that will aid in drafting suitable regulations.

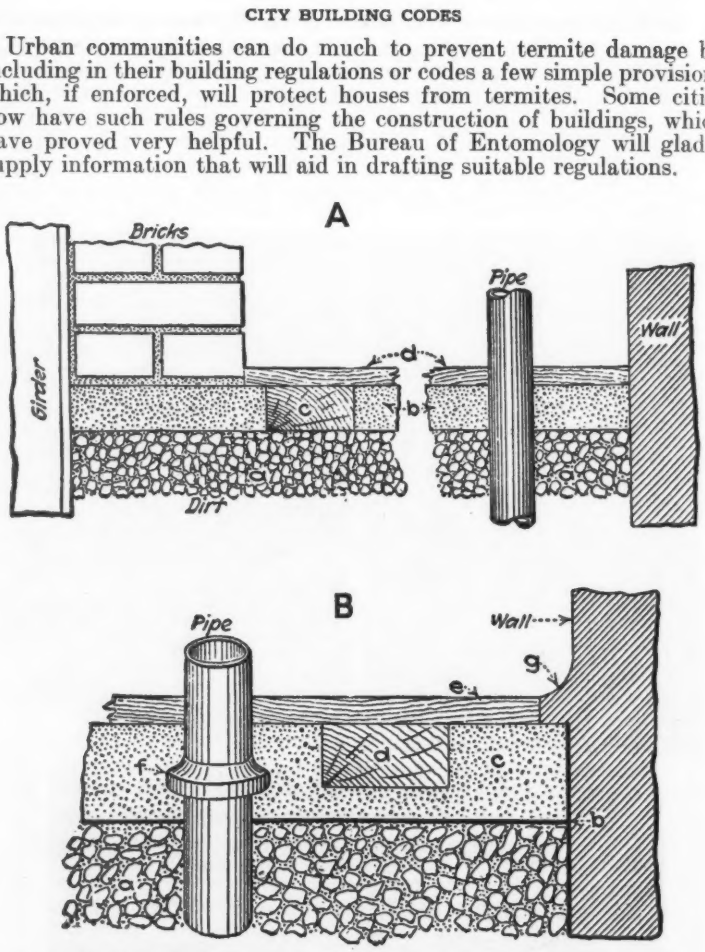

FIGURE 16.—*A*, Improperly constructed concrete flooring: *a*, Gravel or cinders loosely cemented with coarse concrete, 3 inches thick, but with many crevices and holes; *b*, solid, dense concrete, 2 inches thick; *c*, 2- by 4-inch untreated wood sleeper set in moist concrete over the grout; *d*, ⅞-inch pine flooring nailed to sleepers. *B*, Properly constructed concrete flooring: *a*, Gravel or cinders loosely cemented with coarse concrete, but with many crevices and holes; *b*, coal-tar pitch waterproofing ⅛ inch thick; *c*, dense concrete, 3 inches thick; *d*, 2- by 4-inch treated wood sleeper set in a groove in concrete which insulates it from termites in the earth; *e*, ⅞-inch flooring nailed on sleepers; *f*, metal collar around pipe which runs down through the concrete (this collar should be soldered to the pipe and embedded in the concrete); *g*, shoulder of concrete at point of wall and concrete floor to avoid a right-angle connection and consequent cracking.

The principal object is to keep all untreated wood from contact with the ground, where the termites live and from which they get their moisture. The regulations should, therefore, stipulate that no floors, sills, beams, clapboard, etc., of untreated wood may be laid on or in the earth and that untreated beams may not be laid in concrete without at least 1 inch of concrete underneath and separating it from the earth; that no lime mortar may be used in foundations or in cellar

walls where they are in contact with the earth, since termites are able to penetrate lime mortar [6] after some years' service; that all brickwork extending below the surface of the ground shall be faced and capped with concrete at least 1 inch thick; and, where nonsubterranean as well as subterranean termites occur, that only woodwork impregnated with preservatives be used for exterior and interior construction, unless it is impracticable to obtain such treated wood. Sun parlors, porches, steps, etc., in places where there is an earth fill, should be isolated from the main building. For further details see United States Department of Agriculture Leaflet 101, Injury to Buildings by Termites.

LOCATING AND TEMPORARILY ARRESTING THE DAMAGE

Although it may be difficult to eliminate termites and stop further damage by them, when once these insects have become established in

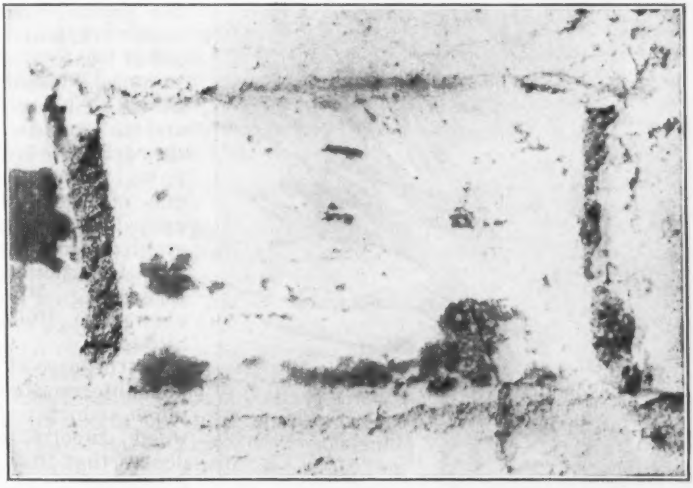

FIGURE 17.—Interior view of portion of whitewashed brick foundation wall of building, below ground level, showing shelter tubes of our common subterranean termite *Reticulitermes* sp., penetrating the disintegrated lime mortar. These termites came through the earth banked up against the exterior wall. To remedy this condition the exterior wall will have to be faced with concrete for some distance below the ground level.

the woodwork of a building, the approximate point of entrance should be sought at once by careful examination of all woodwork in contact with the ground. To do this, it may be necessary to tear up the foundations, flooring, and some other woodwork. The foundation timbers and interior woodwork found damaged should be removed, and the ground where they were set should be broken up and drenched with orthodichlorobenzine at the rate of 1 gallon per 10 linear feet, which will kill or at least temporarily prevent the further activity of termites at that point.

[6] The Bureau of Standards of the U.S. Department of Commerce recommends a mortar composed of 1 part portland cement to 3 parts of sand graded from fine to coarse, with no grains larger than will pass through a no. 10 sieve, to which may be added 10 percent by weight of the cement of some workability agent, such as hydrated lime, for use in locations where termites abound. Such a mortar, it is believed, will have the desirable properties of both cement and lime mortars and, furthermore, will contain a sufficient quantity of cement to prevent the penetration of it by the termites (fig. 17).

INDICATIONS OF INFESTATION

The emergence of large numbers of the flying termites is an indication as well as a warning that the woodwork is infested, and the point of emergence indicates the approximate location of the infested timbers. Large numbers of the dead winged adults or of the discarded wings will usually be found near infested timbers following swarming. Frass and earth thrown out of crevices through which the insects emerge are also evidences of their presence. The presence of branching shelter tubes of small diameter, made of earth mixed with finely powdered wood, on foundation timbers or other woodwork, or over the surface of stone, brick, or other impenetrable foundation material (fig. 13), through which the insects travel from the ground to the woodwork, is another aid in locating infestations. These tubes should be broken off and the ground where they originate broken up and drenched with one of the liquids named in the paragraph under the heading, Destruction of Breeding Places about the Building Site (p. 7).

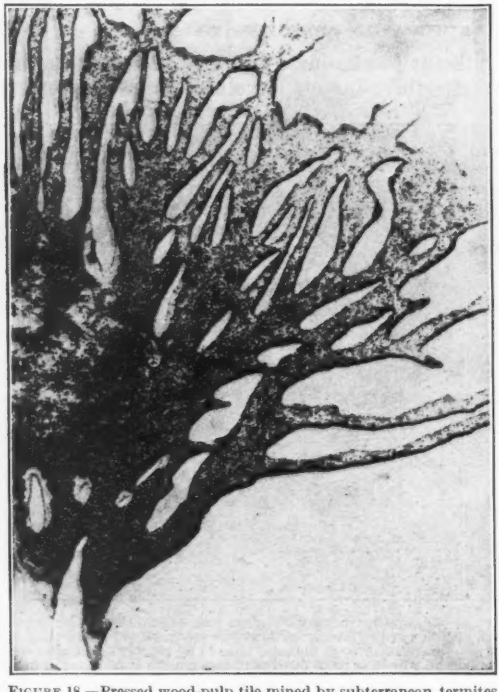

FIGURE 18.—Pressed wood-pulp tile mined by subterranean termites infesting the building, Biloxi, Miss.

In the case of the nonsubterranean termites, which infest wood directly, evidences that they are damaging wood are the impressed pellets of excrement (fig. 14) which are expelled from the wood. Other evidences are the holes, similar in size to BB shot, where the insects entered the wood (fig. 19).

KILLING THE WINGED ADULTS WILL NOT STOP THE DAMAGE

When efforts are made to prevent further damage by termites in buildings, it should be realized that the numbers of these insects may be constantly recruited from some undiscovered, outside, central colony. The destruction of the winged colonizing adults at the time of emergence, although beneficial in preventing the establishment of new colonies, out of doors, will not eradicate the insects infesting the woodwork. These winged adults are harmless indoors and will soon

die. Sweeping them up with a vacuum cleaner is a simple method of getting rid of them. The most destructive forms are the white, wingless workers, which remain within the wood.

DISCONNECTING WOOD FROM THE GROUND

Subterranean termites infesting beams or other wood will die if the wood is disconnected from the ground. Knowledge of this fact will save time and expense, especially in the case of old frame buildings, where extensive repairs would be unwarranted. Disconnecting untreated foundation timbers from contact with the soil will also cause the death of subterranean termites in the other woodwork, furniture, and stored material in the building, even if they have penetrated to the second or third floors. These timbers need not be removed or replaced unless seriously weakened structurally. However, if the wood is kept moist by some other means, such as water leakage, the termites will continue to work and thrive. This applies especially to damp corners of basements near outside water pipes, bathrooms, kitchens, and the like.

FIGURE 19.—Entrance holes of sexual, colonizing adults of a nonsubterranean termite (*Kalotermes hubbardi*) in wood of dead cottonwood tree in Arizona.

REPLACING WOOD WITH CONCRETE

Concrete floors and concrete baseboards should be substituted for wood. Untreated beams penetrating through concrete floors into the earth and the lower parts of door jambs and casings should be cut off at least 6 inches above the ground or floor and replaced with cement plinths, which should project one quarter inch beyond the jambs and casings. Metal strips should be sunk down from the woodwork into the concrete. Wooden thresholds, wainscoting, window sills, subsills, and stools in the basement or ground floor should be removed and placed on concrete (a layer of concrete between the earth and wood (fig. 16, *B*)) or replaced with concrete.

REPLACING WOOD WITH METAL

In basements and cellars steel rails or other structural metal work can sometimes be economically used to replace weakened timbers.

COMBATING TERMITES THAT ARE NONSUBTERRANEAN IN HABIT

Unlike the subterranean termites, nonsubterranean termites do not live in the soil, but fly to and attack wood directly. To combat such termites it is advisable to remove and replace the wood if the

damage is slight and localized. Where the wood has been seriously damaged, but not structurally weakened, saturate the infested wood with orthodichlorobenzene. The wood should be thoroughly saturated with this chemical, a rag or mop being used, dripping wet, or the liquid can be applied as a spray. Several applications may be necessary to kill the insects.

If orthodichlorobenzene is used as a spray, it is advised that the house be opened up before and for some time after treatment, since there is quite an odor to the chemical which may prove disagreeable in a closed room. Also, in spraying timbers overhead care should be taken not to let the liquid drip down, since it might slightly burn the face and hands and would be painful if it got into the eyes.

If the orthodichlorobenzene treatment is not practicable and the wood is too thick for the solution to penetrate, blow dry paris green, or the less dangerous although less effective sodium fluosilicate, by means of a bellows into holes bored with an auger into the infested wood; these holes should penetrate to the galleries of the termites. If, because of moisture, the powder becomes caked, the treatment should be repeated. Wood structurally weakened should be removed and replaced with chemically-treated wood or strengthened with structural steel.

By far the greater and more serious damage to timber in the United States is caused by termites of the subterranean type. Department of Agriculture Leaflet 101, on the prevention of damage by termites in buildings, discusses in detail the control of subterranean termites infesting buildings.

PREVENTING AND REMEDYING INJURY TO LIVING VEGETATION

FRUIT, NUT, SHADE, AND FOREST TREES

Termites cause occasional but serious injury to individual living trees, shrubs, nursery stock, and grapevines. In case of shade trees the infestation may start as local at the base and extend more generally through the heart wood. A wise preventive measure is the removal of all loose wood which may afford them shelter, such as prunings, dead and dying trees, and the like, and untreated fence posts and similar material.

Termites are also occasionally a pest in orchards, not only in new orchards planted on freshly cleared land where there is such debris, but also, because of neglect, in old orchards, in both Florida and California.

Cleanliness in orchard and forest management is important. Since termites in the Southern States render unmerchantable the forest trees that have been killed by insects, fire, or disease, all timber from such trees should be utilized or removed as promptly as possible in areas where termites are common.

In the case of the pecan it is recommended that 2 or 3 cereal crops be grown on newly cleared land before the young trees are set out.

TREE SURGERY

Properly executed tree surgery sometimes is effective in repairing injury by termites to valuable old fruit and shade trees. The termite-infested wood should be carefully cut out, and the dead heartwood should be given a brush treatment with coal-tar creosote. This

treatment should not extend to within an inch of the living sapwood. Then the cavity should be filled with a suitable material.

COVERING SCARS AND PRUNED AREAS

To prevent infestation, care should be taken that the trees do not become scarred, especially near the base. Scars and all pruned areas should be treated with a mixture of one fourth creosote and three fourths coal tar. This mixture should not be allowed to come in contact with the living tissues at the edges of the bark; to protect them a shellac should be applied.

COMMERCIAL FERTILIZERS

Soil heavily manured will attract subterranean termites, since they can obtain food from the animal manure; commercial fertilizers should be used in preference in regions where termites are common in the soil.

YOUNG PLANTATIONS OR NURSERY STOCK

Injury to nursery stock from 1 to 3 years old will be more serious on recently cleared land and where decaying wood is abundant. Any debris in which the insects breed should be removed. In general the use of recently cleared land should be avoided in planting nursery stock. Earth used in banking should be free from rotten wood. Care should be taken not to allow the roots to dry out before being planted, as weakened stock is specially susceptible to attack; particular care should be given grafted stock.

INSECTICIDES

When valuable trees are infested but not yet dying, subterranean termites can be killed in the soil, if it is moist and not too compact, by breaking it up near the tree and pouring carbon disulphide on the earth at a distance of about a foot from the trunk, then covering the liquid over with earth. The gas from this liquid will penetrate the subterranean galleries of the termites. It is somewhat dangerous to plant life, and very large doses should not be used. *Care should be taken in handling this volatile fluid, as the gas or vapor from it is highly inflammable and explosive when mixed with air in certain proportions; no flame should be brought near it, and the fumes should not be inhaled, as they are poisonous.* There are indications that an emulsion of carbon disulphide, which is on the market ready for use, may prove more effective than carbon disulphide alone; as in the case of the disulphide itself, the earth is loosened up and the emulsion poured on, at least a foot from the tree. Carbon tetrachloride,[7] the gas from which is neither explosive nor inflammable, can be similarly used but is apparently not so effective as carbon disulphide. The gases from carbon disulphide and carbon tetrachloride, being heavier than air, will not readily rise.

Where nonsubterranean termites are infesting living trees, they can be poisoned with dry paris green in the manner discussed on page 18.

[7] Carbon tetrachloride is a thin, transparent, colorless, volatile liquid, which forms a gas with a pungent, aromatic odor. Like carbon disulphide, it is heavier than air. Although it is only about one half or one third as effective as carbon disulphide when used at the same dosage rate, it has the great advantage that its gas is neither explosive nor inflammable; there will be no fire risk attending its use in buildings.

VINEYARDS

In vineyards all dead or diseased vines should be removed. All exposed areas left by pruning should be painted with preservative coatings, and the prunings should be burned promptly. Nearby stands of tree windbreaks should be carefully cared for and kept free from infestation by termites. Trellis posts should be creosoted.

FIELD AND TRUCK CROPS

DEEP FALL PLOWING

Deep, late, fall plowing will be of value in breaking up the galleries and nests of subterranean termites on ground planted to field or truck crops. Irrigating the land, where practicable, will be effective; this can be done before planting the crop.

BURNING STUBBLE

Care should be taken not to plow under stubble which will serve as food for termites; it should be burned. The use of commercial fertilizers instead of animal manure is also recommended where subterranean termites are common in the soil.

ROTATION OF CROPS

As a result of the frequent stirring of the soil, rotation of crops will aid in preventing termites from injuring them. Plowing and fallowing are more practical than the use of insecticides in preparing the soil to prevent termite damage.

FLOWERS AND GREENHOUSE STOCK

Termites injure a great variety of flowers in gardens, as well as many plants grown under glass in greenhouses, where the warm, moist atmosphere maintained throughout the year promotes greatly the activity of the insects. Injury from termites is especially common where the plants are perennial and have woody stalks.

SOURCES OF INFESTATION

Heavily manured flower beds are a source of infestation to the stems of the flowers, as well as to the woodwork of buildings near by, if suitable protection is lacking. Termites can obtain food from the animal manure. Untreated wooden stakes used as supports of plants often become infested, and in time the insects attack the plants. Where greenhouses have already been built and termite damage is due to poor construction termites often attack old label sticks, the wooden uprights supporting wooden benches set on or in the ground, and the wooden bench bottoms and plant pots, and later attack the growing plants. The insects come up through the ground and form dirt galleries over the supports, or burrow up through the wooden bench legs and run galleries the full length of the benches. They enter the soil in the pots through the drainage holes and eat out the main stalk of the root, killing the plant very quickly.

PROPER CONSTRUCTION OF GREENHOUSES

Proper construction of greenhouses will practically safeguard plants growing in them from all injury by termites. Iron frames and concrete work should, wherever possible, replace bricks or woodwork.

In cases of infestation of old greenhouses, all wooden uprights supporting wooden plant benches should be sawed off, if set on or in the ground, and rested on stone, bricks, or concrete, above the surface of the ground. Proper repairing, including the removal of all infested wood, will prevent the plants from becoming infested in turn. Where woodwork is necessary the wood should be impregnated with zinc chloride or bichloride of mercury; it can be painted after treatment. Wood impregnated with coal-tar creosote cannot be used with safety in greenhouses.

AVOIDING STABLE MANURE

In flower gardens, especially those located near the woodwork of buildings, commercial fertilizer should be substituted for stable manure in order to protect not only the buildings but also the growing plants.

INSECTICIDES

Either carbon disulphide or carbon tetrachloride [8] can be used to kill termites in the soil if it is moist and not compact. These gases should not be used too near the infested plants, or the plants should be removed temporarily until the soil has been treated. Small holes should be made near the infested plants and a small quantity of the liquid chosen poured in and the holes immediately closed tightly with earth. Calcium cyanide [9] has also been found effective, but it should not be placed near living plants; it mixes readily with and enriches the soil and gives off an insecticidal gas which *should not be inhaled, as it is poisonous.*

An effective control may be found in the use of kerosene nicotine oleate or a 5-percent kerosene emulsion.[10] If the greenhouse benches are infested, but for any reason cannot be replaced, they should be soaked thoroughly with this emulsion, as should also the ashes and sand under the pots on the benches. This may be done by removing the potted plants from a section of the bench, spraying that section, and moving the pots on the bench to cover the treated area, thus giving access to another section. Potted heliotropes and geraniums have been treated directly with the 5-percent kerosene emulsion without injury to the plants, and the white ants in the soil of the pots were all killed. The soil should be wet down before this spray is used. This treatment should be given late in the afternoon and be followed early the next morning with a thorough syringing of the soil with water to wash out the surplus oil. It is important to remove all infested pots from the bench as soon as the infestation is noticed and to destroy the termites with kerosene emulsion.

[8] See footnote 7 (p. 19).

[9] 2 ounces of calcium cyanide to 1 square yard of ground is recommended.

[10] Kerosene emulsion is made as follows: Kerosene, 2 gallons; fish-oil soap, ½ pound; water, 1 gallon. Dissolve the soap in hot water and pour in the oil slowly, with constant stirring to emulsify. Dilution: If 37 gallons of water be added to the above stock emulsion it will give 40 gallons of 5-percent kerosene emulsion.

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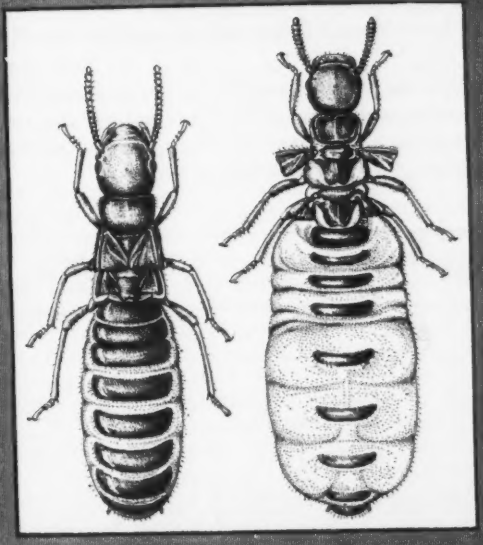
PREVENTING DAMAGE BY TERMITES OR WHITE ANTS



THROUGHOUT the United States, but especially in the Southern, Central, Southwestern, and Pacific Coast States, native termites, or white ants, cause serious damage to the foundations and woodwork of buildings and articles in the buildings, and to living trees, crops, and other vegetation. Damage to buildings, furniture, and similar articles can be prevented by the proper construction of buildings and the chemical treatment of wood, and injury to growing vegetation can be reduced by clean culture and the use of insecticides.

This bulletin describes the habits and activities of subterranean and nonsubterranean termites and sets forth in detail the precautions to be taken against them and the remedies available when damage has been done.

Washington, D. C.

Issued April 1926
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Slightly revised February 1939

PREVENTING DAMAGE BY TERMITES OR WHITE ANTS

By T. E. SNYDER, *senior entomologist, Division of Forest Insect Investigations, Bureau of Entomology and Plant Quarantine*

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TERMITES AND THEIR HABITS

DISTRIBUTION AND FORMS

THE TERMITES, or "white ants", in this country are mostly destructive native insects. Fifty-eight species of them occur in the United States. They are distributed throughout the country, although in the southern, southwestern, and Pacific coast regions, where both the subterranean and nonsubterranean kinds occur (fig. 1), they are more numerous and injurious than elsewhere.

These so-called "white ants" are not true ants, although they look like ants and live in colonies made up of different forms or castes. In these nests or colonies both wingless and winged mature individuals are produced. The brownish or blackish, elongate, slender, antlike, colonizing, sexual adults (fig. 2) with long white wings, unlike the other forms, have functional eyes, and their bodies are able to endure full sunlight. These migratory males and females appear normally once a year during a short period.

There are three stages in the life of termites—the egg, the nymph, and the adult. The adults are of two kinds—sterile and fertile. The sterile adults of our common subterranean termites and of many other species include two forms (or castes)—the soldiers (fig. 3, *a*) and the workers (fig. 3, *b*); and the fertile or sexual adults include three normal forms (fig. 4, *F* to *K*).

LOCATION OF COLONIES OR NESTS

The nests of some species of termites [1] are in the earth and in dead and decaying wood. These more common and injurious species are of subterranean habit, timber and trees being attacked by the workers only through the ground. The nests of some other less common species,[2] however, are excavated in wood and trees by the winged forms, there being no workers and no underground life.

[1] Genera *Reticulitermes* Holmgren, *Heterotermes* Froggatt, *Amitermes* Silvestri, etc.
[2] Genera *Termopsis* Heer, *Kalotermes* Hagen, *Neotermes* Holmgren, *Cryptotermes* Banks, etc.

With the clearing of land and the consequent destruction of their natural breeding places in the dead trees, decaying stumps, and logs of the forests, termites become increasingly destructive to the woodwork and contents of buildings (figs. 5–11), telephone poles, fences, or any timber in contact with the ground, as well as to living vegetation, including not only fruit and shade trees, shrubs, and flowers, but also truck (fig. 12) and field crops and, in California, grapevines. The principal food of termites is cellulose, which they obtain from either dead or living vegetation.

Termites in the United States are mainly species of subterranean or wood-boring habit and are not so spectacular or common as the mound-making or tree-nesting termites of the Tropics. Very few termites in this country have habits that make them conspicuous, or come above ground into the sunlight except during the annual coloniz-

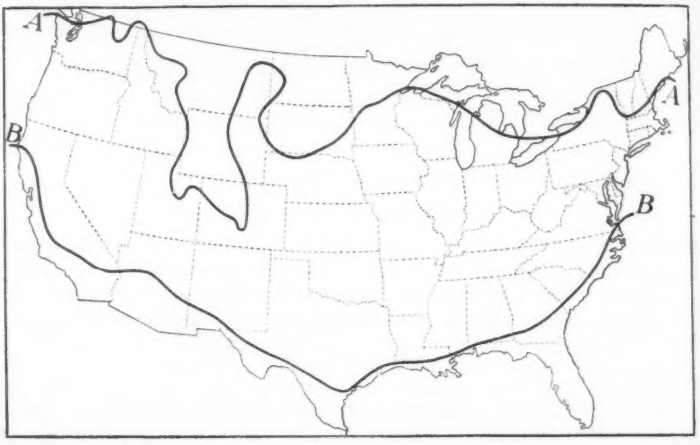

FIGURE 1.—Map showing (line *A-A*) the northern limit of damage done by subterranean termites in the United States and (line *B-B*) the northern limit of damage done by dry-wood or nonsubterranean termites.

ing swarm; hence they largely escape notice until they become injurious.

TERMITES THAT ARE SUBTERRANEAN IN HABIT

Subterranean termites live in forests, building their nests in the wood of standing timber, logs, or stumps; in cleared land, in any wood in contact with the ground; or, in the plains, in a labyrinth of underground passages in the earth, usually underneath wood or vegetation.

Termites are soft-bodied and always conceal themselves within wood, in the earth, or within their earthlike carton shelter tubes (fig. 13). The grayish-white, soft-bodied, wingless, sterile "workers" (fig. 3, *b*) are in reality the destructive form. These workers make the excavations occupied by the colony and enlarge and extend them as the colony increases. They live underground or within the wood, are blind, and shun the light; as a result they are rarely seen. In burrowing through wood the workers often completely honeycomb it, usually following the grain and eating out the softer, thin-walled,

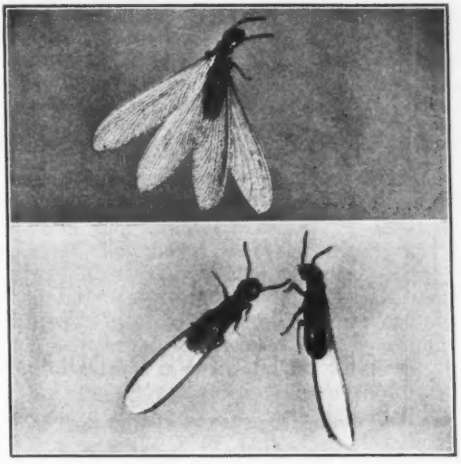

FIGURE 2.—Winged sexual adults of eastern subterranean termites; upper, *Reticulitermes flaripes*, nearly three and one-half times natural size; lower, *R. virginicus*, three times natural size.

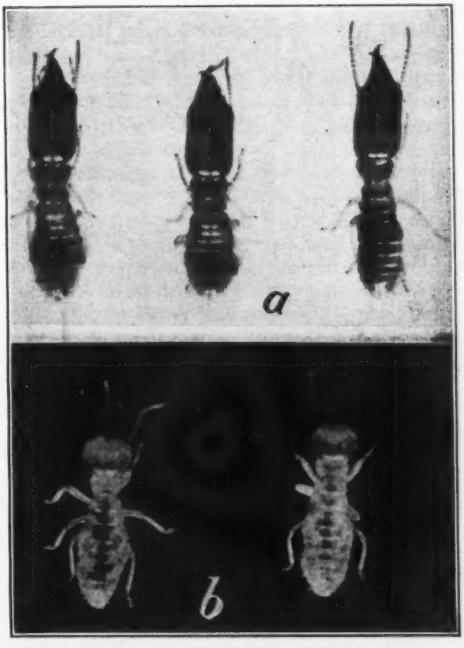

FIGURE 3.—Mature soldiers (*a*) and mature workers (*b*) of the eastern subterranean termite *Reticulitermes flavipes*. Slightly more than six times natural size.

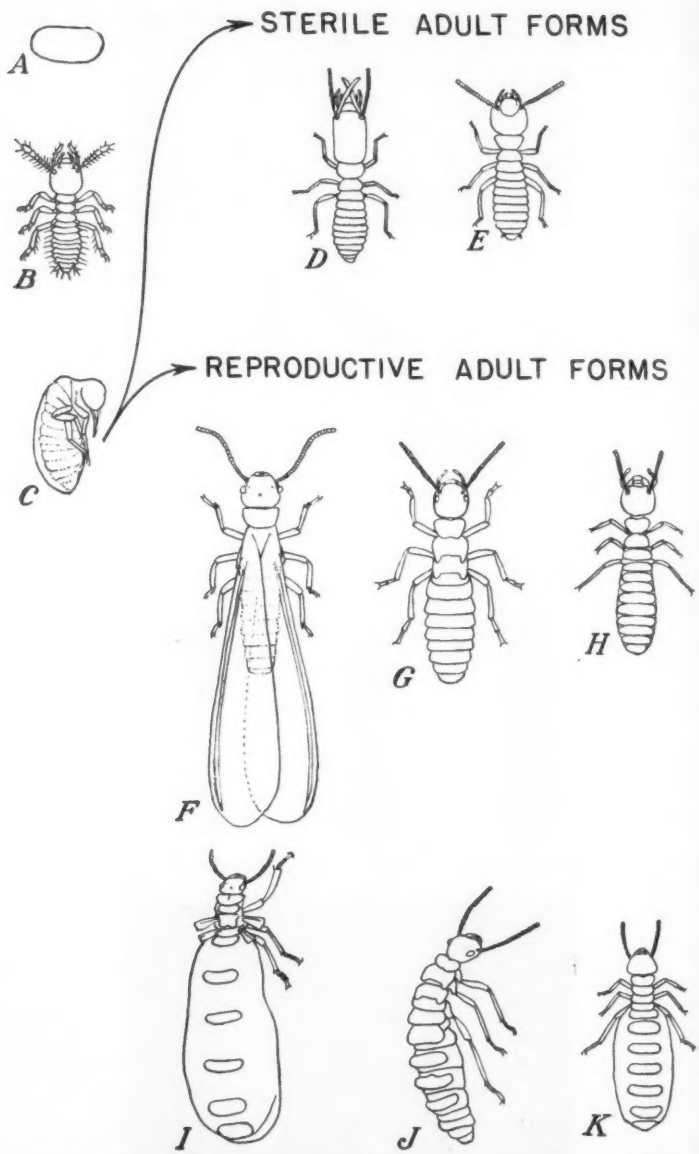

FIGURE 4.—Diagram showing the relationships of the stages and forms of our common subterranean termite *Reticulitermes flavipes*: *A*, Egg; *B*, recently hatched nymph; *C*, immature nymph in quiescent or resting stage; *D*, soldier; *E*, worker; *F*, sexual winged adult; *G*, sexual adult with wing pads; *H*, workerlike wingless sexual adult; *I*, *J*, and *K*, enlarged egg-laying females or queens, corresponding to *F*, *G*, and *H*, respectively. *D* and *E* are sterile adult forms; *F*, *G*, *H*, *I*, *J*, and *K* are fertile or reproductive adult forms. (The enlargements are approximately as follows: *A*, ×16; *B*, ×13½; *C*, ×10; *D*, ×4½; *E*, ×5½; *F*, ×6; *G*, ×4½; *H*, ×5; *I*, ×2½; *J*, ×2½; *K*, ×3.)

larger-celled spring or new wood. They are able to penetrate the hardest of woods, provided they have access to moisture in the ground. In extending their galleries in wood and vegetation, subterranean species carry moisture with them by means of moist excrement mixed with earth.

TERMITES THAT ARE NONSUBTERRANEAN IN HABIT

The nonsubterranean termites which are injurious attack wood directly; but, instead of following the grain continuously, they excavate through it longitudinal chambers of limited length. The sexual adults, after they have lost their wings, and the young or nymphs, are the destructive forms. Their pellets of excrement (fig. 14) are regularly impressed, and sometimes completely fill or block up the burrows in a compact mass; they are often expelled as dry droppings from the infested wood. These termites are destructive to the woodwork and furniture in buildings (fig. 15), as well as to living trees. Apparently they can exist without the great amount of moisture necessary to the life of termites which are subterranean in habit.

THE COLONIZING SWARM

At certain seasons, usually spring or fall, but varying with the species and the locality, the winged, sexual individuals migrate in large numbers from the parent nests. They then lose their wings and breed new colonies. In the case of the subterranean termites, wood and trees are usually entered indirectly through the ground, although sometimes these insects enter trees under bark loosened by sunburn, etc., or through scars or borer holes, provided sufficient moisture is present. Nonsubterranean termites enter the wood directly, or, in the case of trees, through wounds or borer holes or under loose bark; moisture is not necessary.

In the new quarters eggs are laid, the young develop, and in a few years the colony increases in numbers, and the workers are able to feed and care for the reproductive forms—the "king" (title page, left) and "queen" (title page, right)—as well as the soldiers (fig 3, *a*), which are sterile forms adapted to protect the colony from insect enemies, notably the true ants. In recently formed young colonies the rate of egg laying is slow, but mating is repeated, and, although there is at first a gradual increase, later the increase in the numbers of the broods is rapid. In old colonies there are thousands and tens of thousands of individuals.

Egg laying occurs over a considerable period during the warm months in colonies out of doors. In infested buildings artificially heated, where an even temperature is maintained, the insects are active and may lay eggs every month of the year. The number of eggs laid depends on the age of the queen.

THE REPRODUCTIVE FORMS

Owing to the increasing number of eggs that develop within her the queen becomes enlarged, but never loses the power of locomotion. It was once believed that, since the queen mother was the source of the colony life, the termite colony would be exterminated if she were destroyed, but this has been disproved by more recent studies. In addition to the forms that have shed their wings, several different types of reproductive forms occur—forms with wing pads (the undeveloped wings of the nymphs) and wingless reproductive adults.

The winged forms, however, are the normal type and occur as a single pair, whereas there may be hundreds of the other forms heading colonies. The reproductive forms with wing pads and the wholly wingless type usually have little color in the body, and the eyes are

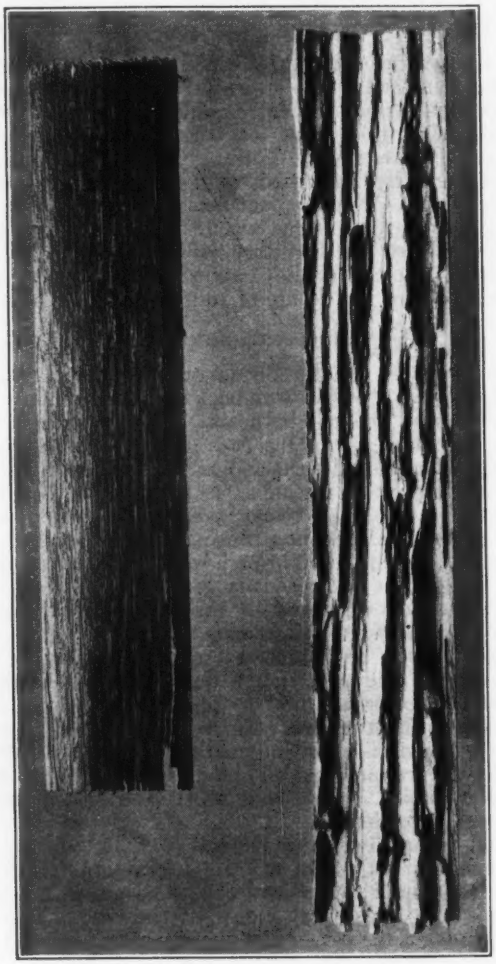

FIGURE 5.—Damage to oak flooring done by the common eastern subterranean termite *Reticulitermes flavipes*. Note that damage is not apparent on the upper surface.

small. These forms rarely come aboveground or leave the burrows in wood.

The location of the queens in the colony depends upon the season of the year. During periods of intense heat or drought in the Plains or in arid or prairie regions the subterranean termites burrow deeply below ground or to a less depth under stones, cow chips, etc. During the winter in the colder climates they burrow below the frost line.

Whole colonies of subterranean termites migrate when conditions become unfavorable. The nonsubterranean termites, on the other

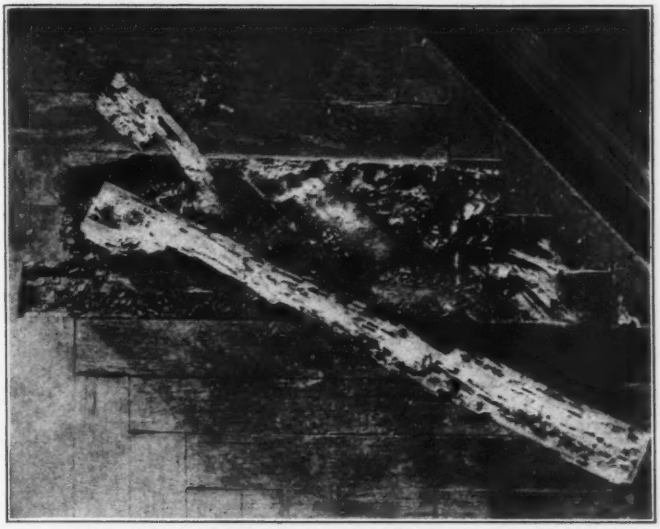

FIGURE 6.—Quartered-oak flooring damaged by the subterranean termite *Reticulitermes flavipes* in an infested building, Washington, D.C., 1915.

hand, are not able to leave the wood in which they have excavated their nests.

PREVENTING AND REMEDYING DAMAGE TO WOODWORK OF BUILDINGS

DESTRUCTION OF BREEDING PLACES ABOUT THE BUILDING SITE

If buildings are to be constructed on recently cleared woodland, decaying logs and stumps should be removed from the soil in the vicinity and burned. If, because of the presence of decaying wood and humus, the subterranean termites are numerous in the earth, the soil should be deeply plowed or otherwise broken up and treated with chemicals to kill the insects. Effective poisons for this purpose are a 10-percent solution of sodium arsenite;[3] 1 part coal-tar creosote and 3 parts kerosene oil (200 gallons per 1,000 square feet) (this mixture, if to be

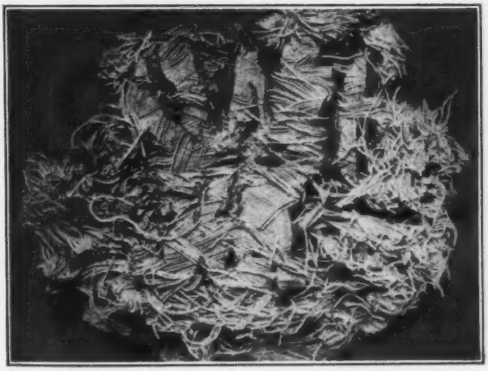

FIGURE 7.—Tube of coarse yarn from bale of cotton on floor of building infested by subterranean termites, Greenville, S.C.

[3] This poison is caustic and should not be used near living vegetation.

applied as a spray, should be strained through burlap before being used); 50-percent carbon disulphide emulsion (1 quart to 50 gallons water, applied at the rate of 3 pints per square foot), which is on the market ready for use; orthodichlorobenzene (100 gallons per 1,000 square feet). Live steam forced into the soil will serve the same purpose as the gases. Decaying fence posts, sidewalks, etc., should be removed and replaced with treated wood, concrete, stone, or other resistant substances; such decaying material would facilitate the formation or perpetuation of the termite colonies.

PROPER CONSTRUCTION OF BUILDINGS

Termites will infest not only old buildings but also improperly constructed new buildings, and these are often badly infested. It is not the age of the building but the manner in which it has been constructed that renders it liable to attack.

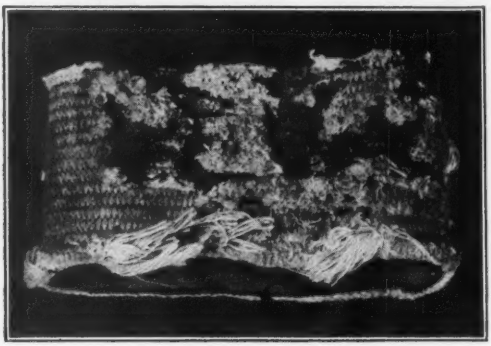

FIGURE 8.—Cotton jacket of rubber-lined fire hose from infested building in Missouri, damaged by subterranean termites (*Reticulitermes* sp.).

INSULATION

Complete insulation from the ground of all untreated woodwork of buildings is the only effective permanent remedy against attack by subterranean termites, and the only relief from their presence. These insects must maintain contact with the ground to obtain the moisture necessary for their existence. When contact with their moisture supply in the earth is cut off, the subterranean insects in the damaged wood, no matter how numerous, soon die.

FOUNDATIONS, SUPPORTS, ETC.

To prevent subterranean termites from reaching the woodwork of buildings from their nests in the ground, the foundations of buildings should be constructed, if possible, entirely of stone, brick, concrete, or concrete and steel,[4] including the pillars in the basement or cellar. The walls, partitions, and flooring in the ground floor, basement, or cellar should also be of concrete. Wooden flooring can be laid over this concrete floor if desired. If the flooring is to be of concrete, the concrete should be laid on a gravel base.

In buildings where stone, brick, or concrete foundations are impracticable, timber impregnated with coal-tar creosote should be employed, and no untreated wood should come in contact with ground which may be infested with termites. Wood to be protected from termites should be impregnated with coal-tar creosote by either the cylinder-pressure or the open-tank process.[5] The open-tank process

[4] In the Southern States, especially in the subtropics, the more valuable permanent buildings should be constructed entirely of steel and concrete.

[5] Under Federal Specifications TT-W-571a, the Department of Agriculture recommends impregnation with coal-tar creosote for timbers to be used in contact with the ground before they are placed in the building; where timbers are to be used above ground and painted or finished, it recommends impregnation with zinc chloride, also before placement.

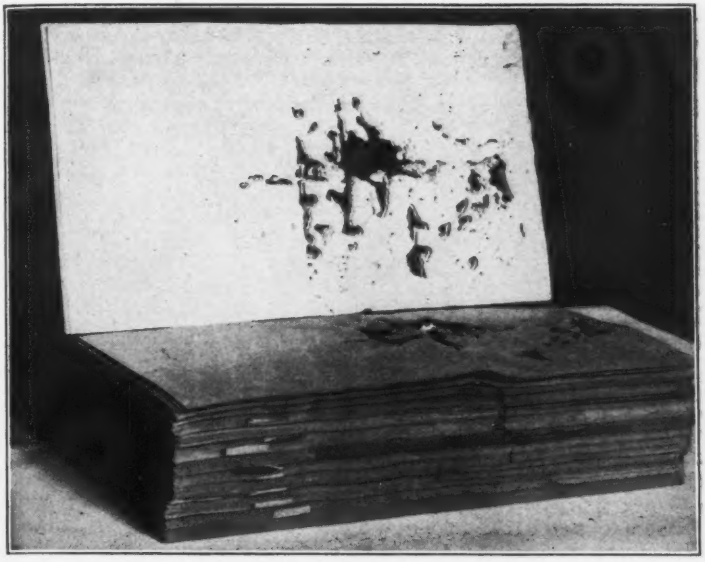

FIGURE 9.—Revenue stamps damaged by the subterranean termite *Reticulitermes flavipes* on infested flooring in the Bureau of Engraving and Printing, Washington, D.C., 1921.

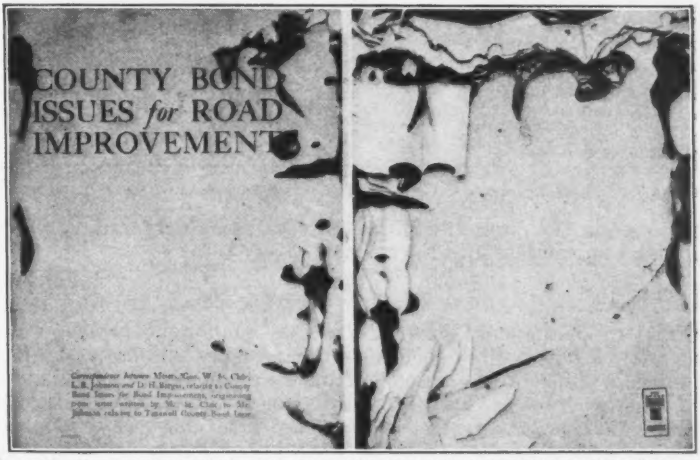

FIGURE 10.—Correspondence and advertisement regarding issue of county bonds; damaged by subterranean termites infesting the building in Virginia in which they were stored.

is simpler, can be made to give satisfactory results where properly used, and can be operated by unskilled labor. If for any reason neither of the foregoing processes can be used, three coats of hot coal-tar creosote brushed on the wood, with sufficient intervals between brushings to permit each coat to dry, will be fairly effective. This method, however, is not generally recommended, since it will preserve the wood for only a few years.

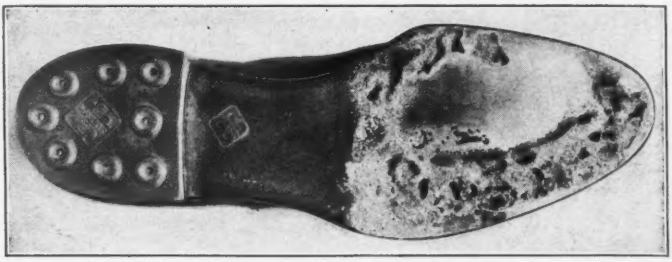

FIGURE 11.—Damage done by the subterranean termite *Reticulitermes flavipes* to shoe stored on infested woodwork in a building in New York City

The supports of porches or steps should never be laid directly on the ground, but should rest on rock or concrete. Window sills and frames in the basement or cellar should be laid over concrete and the woodwork should not come in contact with the ground. The supports of the woodwork of coal bins in basements or cellars should not be set in the ground, but should rest on concrete, not extending through the concrete into the soil.

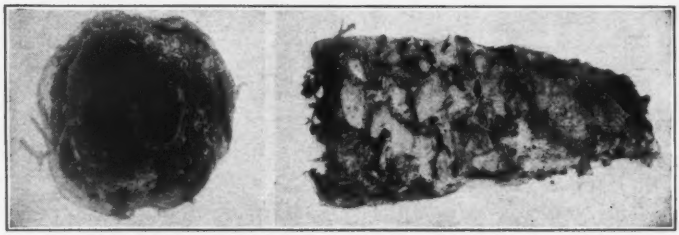

FIGURE 12.—Injury to carrots caused by the subterranean termite *Reticulitermes claripennis*, at Dallas, Tex.

CONCRETE FLOORING

Even in permanent stone or concrete and steel buildings the concrete flooring is often constructed improperly. Usually the base of the concrete floor is a loose combination of coarse gravel or cinders and cement grout. This very rough conglomerate, even if several inches thick, has many cracks and large holes running through it. Over this is laid a layer of solid concrete about 2 or 3 inches thick, of fine texture, in which untreated wooden sleepers are laid while it is still moist. These sleepers nearly or quite reach the coarse, open

conglomerate in contact with the earth, and to them is nailed the wooden flooring (fig. 16, *A*).

It will be seen that this is faulty construction. Termites have free access from the earth, in which they have galleries, through the porous conglomerate, to the untreated beams and flooring. *There should be a layer of solid concrete at least 1 inch thick between the grout and the wood* (fig. 16, *B*).

Among the commonest means of infestation are wooden sleepers or stringers laid in concrete while the latter is still soft, or placed before

FIGURE 13.—Carton, earthlike, shelter tubes constructed by the eastern subterranean termite *Reticulitermes flavipes* over brick wall in dark, heated, damp basement; these tubes are used in passing over impenetrable substances. Inset, near view of tubes showing texture.

the concrete has been poured in. Termites enter through these wooden beams. Other common means of infestation are supports of coal bins extending through concrete and through the disintegrated lime mortar of brick walls.

TERMITE SHIELDS, GUARDS, OR METAL CAPS

Subterranean termites require constant access to soil moisture in order to attack wood. This requirement is supplied when wood is either in contact with the soil or when the termites can reach it through covered, earthlike shelter tubes. These shelter tubes may be constructed over the face of stone, concrete, or brick foundations and along water pipes or similar structures. In consequence they can be kept out of buildings by means of metal barriers. By firmly inserting a sheet of galvanized iron or "termite shield" in the surface of the masonry and letting it project horizontally for 2 inches, then turning the projecting part downward at an angle, communication of termites with the soil, where they obtain moisture, can be cut off. In

less pretentious frame buildings, metal caps should be placed over the tops of all construction stone piling or pillars.

This method is similar to that used in rat-proofing corncribs. It is effective and practicable where untreated timber is placed over masonry foundations.

Again, in the case of stone and steel buildings, the steel or stone pillars or piping extending down through the concrete floor to foundations in the earth often make infestation possible, owing to the fact that the concrete floor does not fit tightly about them. Overlapping strips of metal extending horizontally several inches from the pillars or pipes should be imbedded in the concrete floor in order to obtain a tight joint (fig. 16, *B*); or coal-tar pitch should be poured in to plug up the crevice or frame.

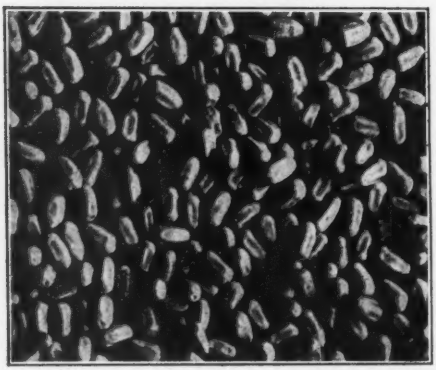

FIGURE 14.—Impressed pellets of excrement of nonsubterranean termites (*Kalotermes* sp.), which drop from infested wood. Greatly enlarged.

AVOIDING DAMPNESS

Dry foundation timbers and basement walls and flooring are important aids in rendering buildings safe from attack by termites. Dampness, warmth, and darkness are favorable to these insects. Concrete floors should be laid on a gravel base, which will prevent dampness and cracking. The points of juncture between concrete walls and wooden flooring should be filled in by rounding off the concrete at these places, since cracks often occur where the wall and floor join at right angles (fig. 16, *B*). Termites often come up through cracks between walls and flooring.

By mixing a heavy mineral residual oil with portland cement, a material is formed almost perfectly nonabsorbent of water and therefore excellent for use in damp-proof construction. Where the various patent or noiseless floorings are used on the ground floor they should always be laid over a concrete base, especially if they contain wood fiber as a constituent.

In no case should untreated beams be completely surrounded with mortar or brick; there should be a space around them sufficient to permit air circulation. Beams should not be set in earth or in moist concrete, but on rock or dry concrete, or in grooves in the latter.

Bungalows or frame buildings which have no cellar should be raised from the ground on stone, concrete, or brick foundations to a height which will allow light and air to penetrate beneath.

LIME MORTAR

Lime mortar sometimes disintegrates after a few years, and termites penetrate through the spaces thus left between the bricks, tiles, etc. Where lime mortar is used below the ground level (fig. 17) the walls should be faced with portland cement 1 inch thick, especially if untreated wood is to come in contact with the bricks.

USE OF CHEMICALLY TREATED WOOD FOR INTERIOR WOODWORK, FURNITURE, ETC.

In the Southern States, especially in the subtropics, in the more valuable permanent buildings the interior woodwork, furniture, etc., should be impregnated with preservatives, since nonsubterranean termites that attack wood directly are common in those regions. Zinc chloride and chlorinated naphthalene [6] are effective preservatives.

Wood-pulp or fiber products, such as the various wood-fiber processed or composition wall and insulating boards, for interior finish

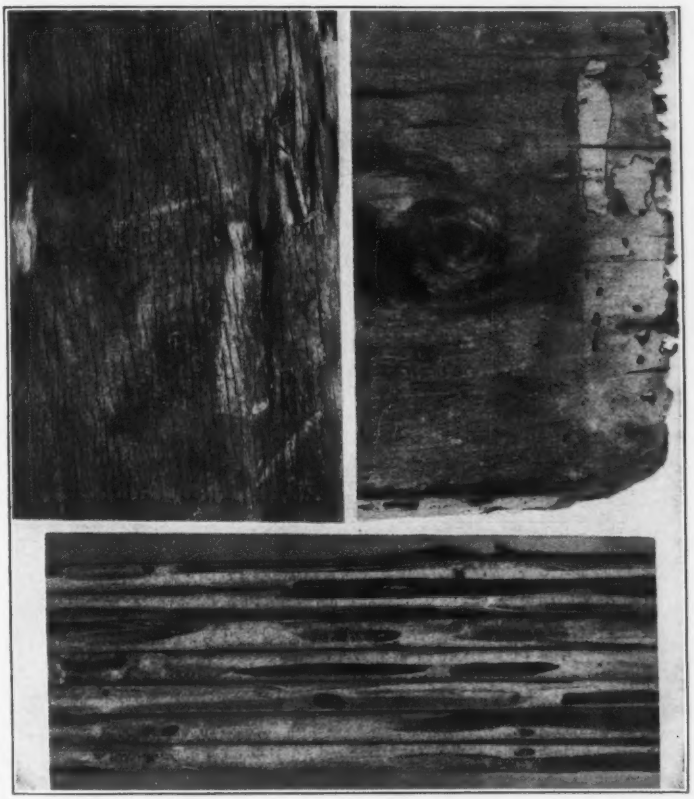

FIGURE 15.—The bottom of a bureau drawer, damaged by the nonsubterranean wood-boring termite *Cryptotermes brevis*, which occurs at Key West, Miami, and Palm Beach, Fla.

and substitutes for lath (fig. 18), or for exterior use, can be protected from attack by termites by adding certain poisons (such as coal-tar creosote at the rate of 2 gallons per 1,000 square feet) to the pulp or fiber laminated boards in the course of manufacture. Experiments with poisoning such products are not yet complete enough to warrant the giving out of definite general recommendations.

[6] This preservative is usually referred to as trichlornaphthalene and, as compared with other chemicals, it is really comparable to a technical product having naphthalene, monochloronaphthalene, dichlornaphthalene, and probably some of the higher chlorinations as impurities. Its melting point ranges between 190° and 210° F.—the specification under which it is sold.

CITY BUILDING CODES

Urban communities can do much to prevent termite damage by including in their building regulations or codes a few simple provisions which, if enforced, will protect houses from termites. Some cities now have such rules governing the construction of buildings, which have proved very helpful. The Bureau of Entomology will gladly supply information that will aid in drafting suitable regulations.

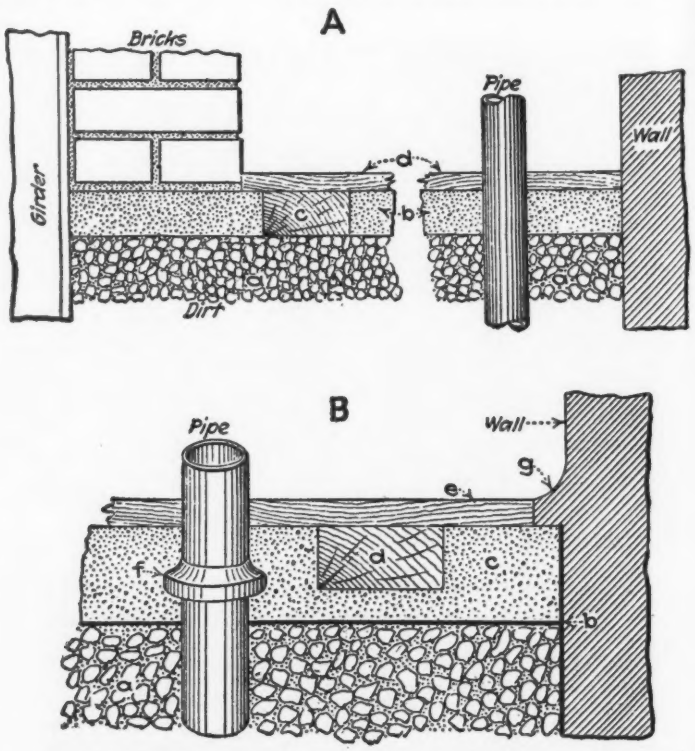

FIGURE 16.—*A*, Improperly constructed concrete flooring: *a*, Gravel or cinders loosely cemented with coarse concrete, 3 inches thick, but with many crevices and holes; *b*, solid, dense concrete, 2 inches thick; *c*, 2- by 4-inch untreated wood sleeper set in moist concrete over the grout; *d*, ¾-inch pine flooring nailed to sleepers. *B*, Properly constructed concrete flooring: *a*, Gravel or cinders loosely cemented with coarse concrete, but with many crevices and holes; *b*, coal-tar pitch waterproofing ⅛ inch thick; *c*, dense concrete, 3 inches thick; *d*, 2- by 4-inch treated wood sleeper set in a groove in concrete which insulates it from termites in the earth; *e*, ¾-inch flooring nailed on sleepers; *f*, metal collar around pipe which runs down through the concrete (this collar should be soldered to the pipe and embedded in the concrete); *g*, shoulder of concrete at point of wall and concrete floor to avoid a right-angle connection and consequent cracking.

The principal object is to keep all untreated wood from contact with the ground, where the termites live and from which they get their moisture. The regulations should, therefore, stipulate that no floors, sills, beams, clapboard, etc., of untreated wood may be laid on or in the earth and that untreated beams may not be laid in concrete without at least 1 inch of concrete underneath and separating it from the earth; that no lime mortar may be used in foundations or in cellar

walls where they are in contact with the earth, since termites are able to penetrate lime mortar[7] after some years' service; that all brickwork extending below the surface of the ground shall be faced and capped with concrete at least 1 inch thick; and, where nonsubterranean as well as subterranean termites occur, that only woodwork impregnated with preservatives be used for exterior and interior construction, unless it is impracticable to obtain such treated wood. Sun parlors, porches, steps, etc., in places where there is an earth fill, should be isolated from the main building. For further details see United States Department of Agriculture Leaflet 101, Injury to Buildings by Termites.

LOCATING AND TEMPORARILY ARRESTING THE DAMAGE

Although it may be difficult to eliminate termites and stop further damage by them, when once these insects have become established in

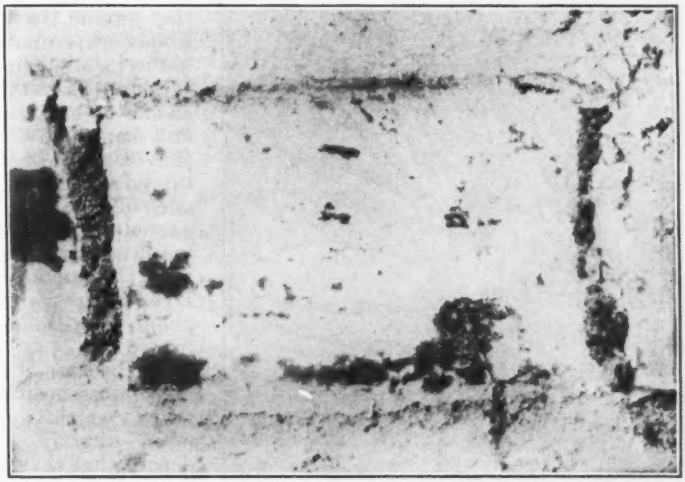

FIGURE 17.—Interior view of portion of whitewashed brick foundation wall of building, below ground level, showing shelter tubes of our common subterranean termite *Reticulitermes* sp., penetrating the disintegrated lime mortar. These termites came through the earth banked up against the exterior wall. To remedy this condition the exterior wall will have to be faced with concrete for some distance below the ground level.

the woodwork of a building, the approximate point of entrance should be sought at once by careful examination of all woodwork in contact with the ground. To do this, it may be necessary to tear up the foundations, flooring, and some other woodwork. The foundation timbers and interior woodwork found damaged should be removed, and the ground where they were set should be broken up and drenched either with orthodichlorobenzine or with a mixture composed of 1 part of coal-tar creosote and 3 parts of a light petroleum oil, such as kerosene, at the rate of 2 gallons per 10 linear feet, which will kill or at least temporarily prevent the further activity of termites at that point.

[7] The Bureau of Standards of the U. S. Department of Commerce recommends a mortar composed of 1 part portland cement to 3 parts of sand graded from fine to coarse, with no grains larger than will pass through a no. 10 sieve, to which may be added 10 percent by weight of the cement or some workability agent, such as hydrated lime, for use in locations where termites abound. Such a mortar, it is believed, will have the desirable properties of both cement and lime mortars and furthermore, will contain a sufficient quantity of cement to prevent the penetration of it by the termites (fig. 17).

INDICATIONS OF INFESTATION

The emergence of large numbers of the flying termites is an indication as well as a warning that the woodwork is infested, and the point of emergence indicates the approximate location of the infested timbers. Large numbers of the dead winged adults or of the discarded wings will usually be found near infested timbers following swarming. Frass and earth thrown out of crevices through which the insects emerge are also evidences of their presence. The presence of branching shelter tubes of small diameter, made of earth mixed with finely powdered wood, on foundation timbers or other woodwork, or over the surface of stone, brick, or other impenetrable foundation material (fig. 13), through which the insects travel from the ground to the woodwork, is another aid in locating infestations. These tubes should be broken off and the ground where they originate broken up and drenched with one of the liquids named in the paragraph under the heading, Destruction of Breeding Places about the Building Site (p. 7).

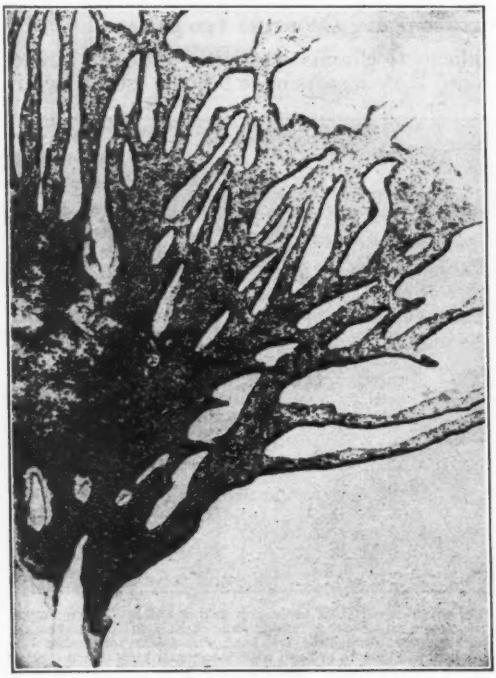

FIGURE 18.—Pressed wood-pulp tile mined by subterranean termites infesting the building, Biloxi, Miss.

In the case of the nonsubterranean termites, which infest wood directly, evidences that they are damaging wood are the impressed pellets of excrement (fig. 14) which are expelled from the wood. Other evidences are the holes, similar in size to BB shot, where the insects entered the wood (fig. 19).

KILLING THE WINGED ADULTS WILL NOT STOP THE DAMAGE

When efforts are made to prevent further damage by termites in buildings, it should be realized that the numbers of these insects may be constantly recruited from some undiscovered, outside, central colony. The destruction of the winged colonizing adults at the time of emergence, although beneficial in preventing the establishment of new colonies, out of doors, will not eradicate the insects infesting the woodwork. These winged adults are harmless indoors and will soon

die. Sweeping them up with a vacuum cleaner is a simple method of getting rid of them. The most destructive forms are the white, wingless workers, which remain within the wood.

DISCONNECTING WOOD FROM THE GROUND

Subterranean termites infesting beams or other wood will die if the wood is disconnected from the ground. Knowledge of this fact will save time and expense, especially in the case of old frame buildings, where extensive repairs would be unwarranted. Disconnecting untreated foundation timbers from contact with the soil will also cause the death of subterranean termites in the other woodwork, furniture, and stored material in the building, even if they have penetrated to the second or third floors. These timbers need not be removed or replaced unless seriously weakened structurally. However, if the wood is kept moist by some other means, such as water leakage, the termites will continue to work and thrive. This applies especially to damp corners of basements near outside water pipes, bathrooms, kitchens, and the like.

FIGURE 19.—Entrance holes of sexual, colonizing adults of a nonsubterranean termite (*Kalotermes hubbardi*) in wood of dead cottonwood tree in Arizona.

REPLACING WOOD WITH CONCRETE

Concrete floors and concrete baseboards should be substituted for wood. Untreated beams penetrating through concrete floors into the earth and the lower parts of door jambs and casings should be cut off at least 6 inches above the ground or floor and replaced with cement plinths, which should project one quarter inch beyond the jambs and casings. Metal strips should be sunk down from the woodwork into the concrete. Wooden thresholds, wainscoting, window sills, subsills, and stools in the basement or ground floor should be removed and placed on concrete (a layer of concrete between the earth and wood (fig. 16, *B*)) or replaced with concrete.

REPLACING WOOD WITH METAL

In basements and cellars steel rails or other structural metal work can sometimes be economically used to replace weakened timbers.

COMBATING TERMITES THAT ARE NONSUBTERRANEAN IN HABIT

Unlike the subterranean termites, nonsubterranean termites do not live in the soil, but fly to and attack wood directly. To combat such termites it is advisable to remove and replace the wood if the

damage is slight and localized. Where the wood has been seriously damaged, but not structurally weakened, saturate the infested wood with orthodichlorobenzene. The wood should be thoroughly saturated with this chemical, a rag or mop being used, dripping wet, or the liquid can be applied as a spray. Several applications may be necessary to kill the insects.

If orthodichlorobenzene is used as a spray, it is advised that the house be opened up before and for some time after treatment, since there is quite an odor to the chemical which may prove disagreeable in a closed room. Also, in spraying timbers overhead care should be taken not to let the liquid drip down, since it might slightly burn the face and hands and would be painful if it got into the eyes.

If the orthodichlorobenzene treatment is not practicable and the wood is too thick for the solution to penetrate, blow dry paris green, or the less dangerous although less effective sodium fluosilicate, by means of a bellows into holes bored with an auger into the infested wood; these holes should penetrate to the galleries of the termites. If, because of moisture, the powder becomes caked, the treatment should be repeated. Wood structurally weakened should be removed and replaced with chemically-treated wood [8] or strengthened with structural steel.

By far the greater and more serious damage to timber in the United States is caused by termites of the subterranean type. Department of Agriculture Leaflet 101, on the prevention of damage by termites in buildings, discusses in detail the control of subterranean termites infesting buildings.

PREVENTING AND REMEDYING INJURY TO LIVING VEGETATION

FRUIT, NUT, SHADE, AND FOREST TREES

Termites cause occasional but serious injury to individual living trees, shrubs, nursery stock, and grapevines. In case of shade trees the infestation may start as local at the base and extend more generally through the heart wood. A wise preventive measure is the removal of all loose wood which may afford them shelter, such as prunings, dead and dying trees, and the like, and untreated fence posts and similar material.

Termites are also occasionally a pest in orchards, not only in new orchards planted on freshly cleared land where there is such debris, but also, because of neglect, in old orchards, in both Florida and California.

Cleanliness in orchard and forest management is important. Since termites in the Southern States render unmerchantable the forest trees that have been killed by insects, fire, or disease, all timber from such trees should be utilized or removed as promptly as possible in areas where termites are common.

In the case of the pecan it is recommended that 2 or 3 cereal crops be grown on newly cleared land before the young trees are set out.

TREE SURGERY

Properly executed tree surgery sometimes is effective in repairing injury by termites to valuable old fruit and shade trees. The termite-infested wood should be carefully cut out, and the dead heartwood should be given a brush treatment with coal-tar creosote. This

[8] See footnote 5, page 8.

treatment should not extend to within an inch of the living sapwood. Then the cavity should be filled with a suitable material.

COVERING SCARS AND PRUNED AREAS

To prevent infestation, care should be taken that the trees do not become scarred, especially near the base. Scars and all pruned areas should be treated with a mixture of one fourth creosote and three fourths coal tar. This mixture should not be allowed to come in contact with the living tissues at the edges of the bark; to protect them a shellac should be applied.

COMMERCIAL FERTILIZERS

Soil heavily manured will attract subterranean termites, since they can obtain food from the animal manure; commercial fertilizers should be used in preference in regions where termites are common in the soil.

YOUNG PLANTATIONS OR NURSERY STOCK

Injury to nursery stock from 1 to 3 years old will be more serious on recently cleared land and where decaying wood is abundant. Any debris in which the insects breed should be removed. In general the use of recently cleared land should be avoided in planting nursery stock. Earth used in banking should be free from rotten wood. Care should be taken not to allow the roots to dry out before being planted, as weakened stock is specially susceptible to attack; particular care should be given grafted stock.

INSECTICIDES

When valuable trees are infested but not yet dying, subterranean termites can be killed in the soil, if it is moist and not too compact, by breaking it up near the tree and pouring carbon disulphide on the earth at a distance of about a foot from the trunk, then covering the liquid over with earth. The gas from this liquid will penetrate the subterranean galleries of the termites. It is somewhat dangerous to plant life, and very large doses should not be used. *Care should be taken in handling this volatile fluid, as the gas or vapor from it is highly inflammable and explosive when mixed with air in certain proportions; no flame should be brought near it, and the fumes should not be inhaled, as they are poisonous.* There are indications that an emulsion of carbon disulphide, which is on the market ready for use, may prove more effective than carbon disulphide alone; as in the case of the disulphide itself, the earth is loosened up and the emulsion poured on, at least a foot from the tree. Carbon tetrachloride,[9] the gas from which is neither explosive nor inflammable, can be similarly used but is apparently not so effective as carbon disulphide. The gases from carbon disulphide and carbon tetrachloride, being heavier than air, will not readily rise.

Where nonsubterranean termites are infesting living trees, they can be poisoned with dry paris green in the manner discussed on page 18.

[9] Carbon tetrachloride is a thin, transparent, colorless, volatile liquid, which forms a gas with a pungent, aromatic odor. Like carbon disulphide, it is heavier than air. Although it is only about one half or one third as effective as carbon disulphide when used at the same dosage rate, it has the great advantage that its gas is neither explosive nor inflammable; there will be no fire risk attending its use in buildings.

VINEYARDS

In vineyards all dead or diseased vines should be removed. All exposed areas left by pruning should be painted with preservative coatings, and the prunings should be burned promptly. Nearby stands of tree windbreaks should be carefully cared for and kept free from infestation by termites. Trellis posts should be creosoted.

FIELD AND TRUCK CROPS

DEEP FALL PLOWING

Deep, late, fall plowing will be of value in breaking up the galleries and nests of subterranean termites on ground planted to field or truck crops. Irrigating the land, where practicable, will be effective; this can be done before planting the crop.

BURNING STUBBLE

Care should be taken not to plow under stubble which will serve as food for termites; it should be burned. The use of commercial fertilizers instead of animal manure is also recommended where subterranean termites are common in the soil.

ROTATION OF CROPS

As a result of the frequent stirring of the soil, rotation of crops will aid in preventing termites from injuring them. Plowing and fallowing are more practical than the use of insecticides in preparing the soil to prevent termite damage.

FLOWERS AND GREENHOUSE STOCK

Termites injure a great variety of flowers in gardens, as well as many plants grown under glass in greenhouses, where the warm, moist atmosphere maintained throughout the year promotes greatly the activity of the insects. Injury from termites is especially common where the plants are perennial and have woody stalks.

SOURCES OF INFESTATION

Heavily manured flower beds are a source of infestation to the stems of the flowers, as well as to the woodwork of buildings near by, if suitable protection is lacking. Termites can obtain food from the animal manure. Untreated wooden stakes used as supports of plants often become infested, and in time the insects attack the plants. Where greenhouses have already been built and termite damage is due to poor construction termites often attack old label sticks, the wooden uprights supporting wooden benches set on or in the ground, and the wooden bench bottoms and plant pots, and later attack the growing plants. The insects come up through the ground and form dirt galleries over the supports, or burrow up through the wooden bench legs and run galleries the full length of the benches. They enter the soil in the pots through the drainage holes and eat out the main stalk of the root, killing the plant very quickly.

PROPER CONSTRUCTION OF GREENHOUSES

Proper construction of greenhouses will practically safeguard plants growing in them from all injury by termites. Iron frames and concrete work should, wherever possible, replace bricks or woodwork.

XUM

In cases of infestation of old greenhouses, all wooden uprights supporting wooden plant benches should be sawed off, if set on or in the ground, and rested on stone, bricks, or concrete, above the surface of the ground. Proper repairing, including the removal of all infested wood, will prevent the plants from becoming infested in turn. Where woodwork is necessary the wood should be impregnated with zinc chloride or bichloride of mercury; it can be painted after treatment. Wood impregnated with coal-tar creosote cannot be used with safety in greenhouses.

AVOIDING STABLE MANURE

In flower gardens, especially those located near the woodwork of buildings, commercial fertilizer should be substituted for stable manure in order to protect not only the buildings but also the growing plants.

INSECTICIDES

Either carbon disulphide or carbon tetrachloride [10] can be used to kill termites in the soil if it is moist and not compact. These gases should not be used too near the infested plants, or the plants should be removed temporarily until the soil has been treated. Small holes should be made near the infested plants and a small quantity of the liquid chosen poured in and the holes immediately closed tightly with earth. Calcium cyanide [11] has also been found effective, but it should not be placed near living plants; it mixes readily with and enriches the soil and gives off an insecticidal gas which *should not be inhaled, as it is poisonous.*

An effective control may be found in the use of kerosene nicotine oleate or a 5-percent kerosene emulsion.[12] If the greenhouse benches are infested, but for any reason cannot be replaced, they should be soaked thoroughly with this emulsion, as should also the ashes and sand under the pots on the benches. This may be done by removing the potted plants from a section of the bench, spraying that section, and moving the pots on the bench to cover the treated area, thus giving access to another section. Potted heliotropes and geraniums have been treated directly with the 5-percent kerosene emulsion without injury to the plants, and the white ants in the soil of the pots were all killed. The soil should be wet down before this spray is used. This treatment should be given late in the afternoon and be followed early the next morning with a thorough syringing of the soil with water to wash out the surplus oil. It is important to remove all infested pots from the bench as soon as the infestation is noticed and to destroy the termites with kerosene emulsion.

[10] See footnote 9 (p. 19).

[11] 2 ounces of calcium cyanide to 1 square yard of ground is recommended.

[12] Kerosene emulsion is made as follows: Kerosene, 2 gallons; fish-oil soap, ½ pound; water, 1 gallon. Dissolve the soap in hot water and pour in the oil slowly, with constant stirring to emulsify. Dilution: If 37 gallons of water be added to the above stock emulsion it will give 40 gallons of 5-percent kerosene emulsion.

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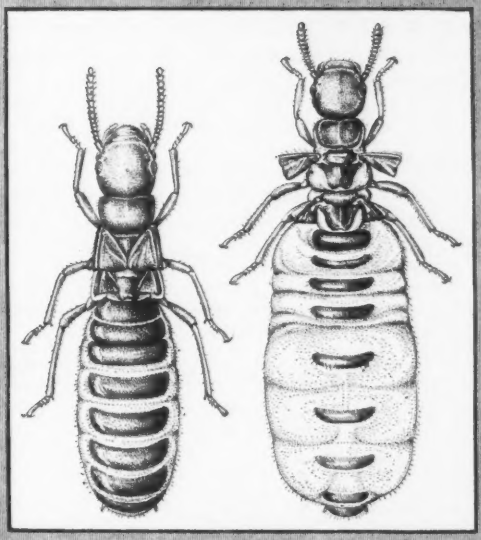
FARMERS' BULLETIN No. 1472
Aug. 1939

PREVENTING DAMAGE BY TERMITES OR WHITE ANTS



THROUGHOUT the United States, but especially in the Southern, Central, Southwestern, and Pacific Coast States, native termites, or white ants, cause serious damage to the foundations and woodwork of buildings and articles in the buildings, and to living trees, crops, and other vegetation. Damage to buildings, furniture, and similar articles can be prevented by the proper construction of buildings and the chemical treatment of wood, and injury to growing vegetation can be reduced by clean culture and the use of insecticides.

This bulletin describes the habits and activities of subterranean and nonsubterranean termites and sets forth in detail the precautions to be taken against them and the remedies available when damage has been done.

Washington, D. C.

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PREVENTING DAMAGE BY TERMITES OR WHITE ANTS

By T. E. SNYDER, *senior entomologist, Division of Forest Insect Investigations, Bureau of Entomology and Plant Quarantine*

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TERMITES AND THEIR HABITS

DISTRIBUTION AND FORMS

THE TERMITES, or "white ants", in this country are mostly destructive native insects. Fifty-eight species of them occur in the United States. They are distributed throughout the country, although in the southern, southwestern, and Pacific coast regions, where both the subterranean and nonsubterranean kinds occur (fig. 1), they are more numerous and injurious than elsewhere.

These so-called "white ants" are not true ants, although they look like ants and live in colonies made up of different forms or castes. In these nests or colonies both wingless and winged mature individuals are produced. The brownish or blackish, elongate, slender, antlike, colonizing, sexual adults (fig. 2) with long white wings, unlike the other forms, have functional eyes, and their bodies are able to endure full sunlight. These migratory males and females appear normally once a year during a short period.

There are three stages in the life of termites—the egg, the nymph, and the adult. The adults are of two kinds—sterile and fertile. The sterile adults of our common subterranean termites and of many other species include two forms (or castes)—the soldiers (fig. 3, *a*) and the workers (fig. 3, *b*); and the fertile or sexual adults include three normal forms (fig. 4, *F* to *K*).

LOCATION OF COLONIES OR NESTS

The nests of some species of termites [1] are in the earth and in dead and decaying wood. These more common and injurious species are of subterranean habit, timber and trees being attacked by the workers only through the ground. The nests of some other less common species,[2] however, are excavated in wood and trees by the winged forms, there being no workers and no underground life.

[1] Genera *Reticulitermes* Holmgren, *Heterotermes* Froggatt, *Amitermes* Silvestri, etc.
[2] Genera *Termopsis* Heer, *Kalotermes* Hagen, *Neotermes* Holmgren, *Cryptotermes* Banks, etc.

With the clearing of land and the consequent destruction of their natural breeding places in the dead trees, decaying stumps, and logs of the forests, termites become increasingly destructive to the woodwork and contents of buildings (figs. 5–11), telephone poles, fences, or any timber in contact with the ground, as well as to living vegetation, including not only fruit and shade trees, shrubs, and flowers, but also truck (fig. 12) and field crops and, in California, grapevines. The principal food of termites is cellulose, which they obtain from either dead or living vegetation.

Termites in the United States are mainly species of subterranean or wood-boring habit and are not so spectacular or common as the mound-making or tree-nesting termites of the Tropics. Very few termites in this country have habits that make them conspicuous, or come above ground into the sunlight except during the annual coloniz-

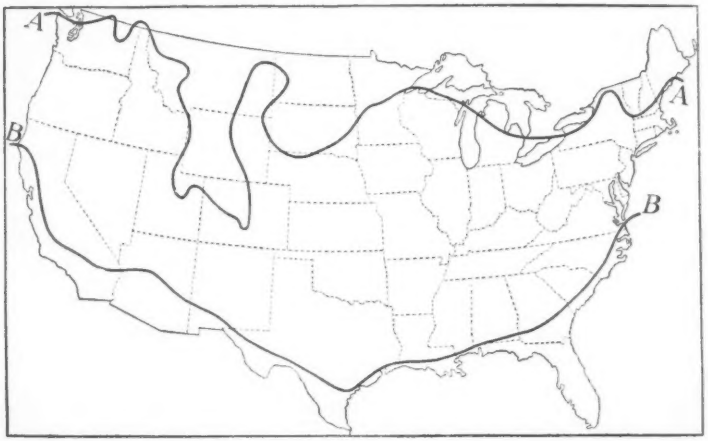

FIGURE 1.—Map showing (line *A–A*) the northern limit of damage done by subterranean termites in the United States and (line *B–B*) the northern limit of damage done by dry-wood or nonsubterranean termites.

ing swarm; hence they largely escape notice until they become injurious.

TERMITES THAT ARE SUBTERRANEAN IN HABIT

Subterranean termites live in forests, building their nests in the wood of standing timber, logs, or stumps; in cleared land, in any wood in contact with the ground; or, in the plains, in a labyrinth of underground passages in the earth, usually underneath wood or vegetation.

Termites are soft-bodied and always conceal themselves within wood, in the earth, or within their earthlike carton shelter tubes (fig. 13). The grayish-white, soft-bodied, wingless, sterile "workers" (fig. 3, *b*) are in reality the destructive form. These workers make the excavations occupied by the colony and enlarge and extend them as the colony increases. They live underground or within the wood, are blind, and shun the light; as a result they are rarely seen. In burrowing through wood the workers often completely honeycomb it, usually following the grain and eating out the softer, thin-walled,

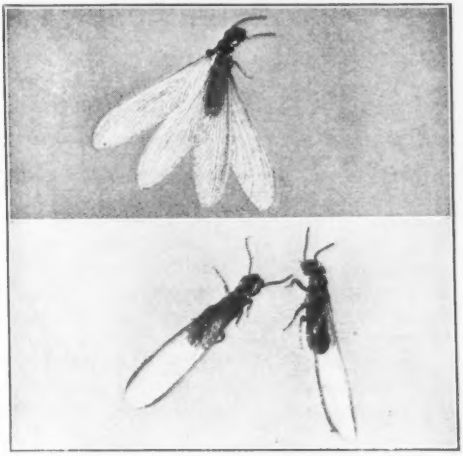

FIGURE 2.—Winged sexual adults of eastern subterranean termites; upper, *Reticulitermes flavipes*, nearly three and one-half times natural size; lower, *R. virginicus*, three times natural size.

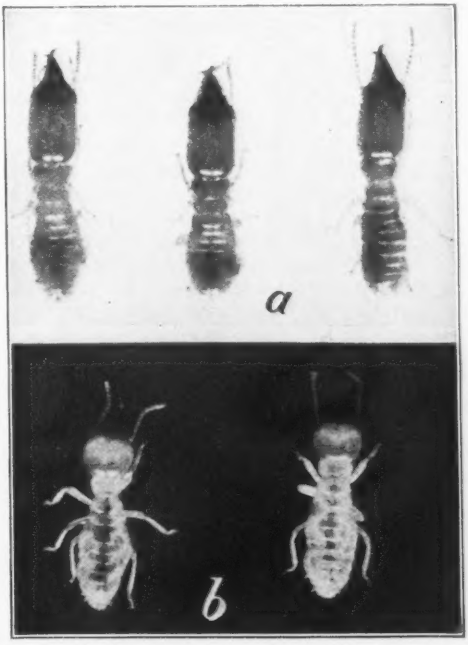

FIGURE 3.—Mature soldiers (*a*) and mature workers (*b*) of the eastern subterranean termite *Reticulitermes flavipes*. Slightly more than six times natural size.

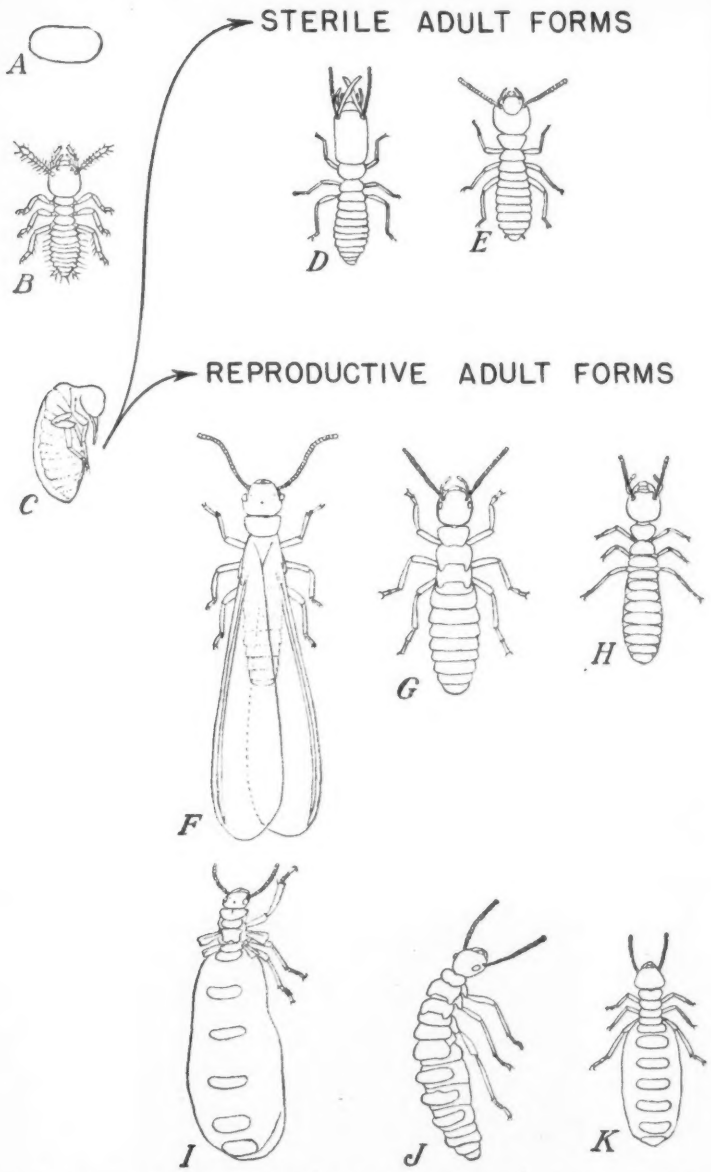

FIGURE 4.—Diagram showing the relationships of the stages and forms of our common subterranean termite *Reticulitermes flavipes:* *A*, Egg; *B*, recently hatched nymph; *C*, immature nymph in quiescent or resting stage; *D*, soldier; *E*, worker; *F*, sexual winged adult; *G*, sexual adult with wing pads; *H*, workerlike wingless sexual adult; *I*, *J*, and *K*, enlarged egg-laying females or queens, corresponding to *F*, *G*, and *H*, respectively. *D* and *E* are sterile adult forms; *F*, *G*, *H*, *I*, *J*, and *K* are fertile or reproductive adult forms. (The enlargements are approximately as follows: *A*, ×16; *B*, ×13½; *C*, ×10; *D*, ×4½; *E*, ×5½; *F*, ×6; *G*, ×4½; *H*, ×5; *I*, ×2½; *J*, ×2½; *K*, ×3.)

larger-celled spring or new wood. They are able to penetrate the hardest of woods, provided they have access to moisture in the ground. In extending their galleries in wood and vegetation, subterranean species carry moisture with them by means of moist excrement mixed with earth.

TERMITES THAT ARE NONSUBTERRANEAN IN HABIT

The nonsubterranean termites which are injurious attack wood directly; but, instead of following the grain continuously, they excavate through it longitudinal chambers of limited length. The sexual adults, after they have lost their wings, and the young or nymphs, are the destructive forms. Their pellets of excrement (fig. 14) are regularly impressed, and sometimes completely fill or block up the burrows in a compact mass; they are often expelled as dry droppings from the infested wood. These termites are destructive to the woodwork and furniture in buildings (fig. 15), as well as to living trees. Apparently they can exist without the great amount of moisture necessary to the life of termites which are subterranean in habit.

THE COLONIZING SWARM

At certain seasons, usually spring or fall, but varying with the species and the locality, the winged, sexual individuals migrate in large numbers from the parent nests. They then lose their wings and breed new colonies. In the case of the subterranean termites, wood and trees are usually entered indirectly through the ground, although sometimes these insects enter trees under bark loosened by sunburn, etc., or through scars or borer holes, provided sufficient moisture is present. Nonsubterranean termites enter the wood directly, or, in the case of trees, through wounds or borer holes or under loose bark; moisture is not necessary.

In the new quarters eggs are laid, the young develop, and in a few years the colony increases in numbers, and the workers are able to feed and care for the reproductive forms—the "king" (title page, left) and "queen" (title page, right)—as well as the soldiers (fig 3, *a*), which are sterile forms adapted to protect the colony from insect enemies, notably the true ants. In recently formed young colonies the rate of egg laying is slow, but mating is repeated, and, although there is at first a gradual increase, later the increase in the numbers of the broods is rapid. In old colonies there are thousands and tens of thousands of individuals.

Egg laying occurs over a considerable period during the warm months in colonies out of doors. In infested buildings artificially heated, where an even temperature is maintained, the insects are active and may lay eggs every month of the year. The number of eggs laid depends on the age of the queen.

THE REPRODUCTIVE FORMS

Owing to the increasing number of eggs that develop within her the queen becomes enlarged, but never loses the power of locomotion. It was once believed that, since the queen mother was the source of the colony life, the termite colony would be exterminated if she were destroyed, but this has been disproved by more recent studies. In addition to the forms that have shed their wings, several different types of reproductive forms occur—forms with wing pads (the undeveloped wings of the nymphs) and wingless reproductive adults.

The winged forms, however, are the normal type and occur as a single pair, whereas there may be hundreds of the other forms heading colonies. The reproductive forms with wing pads and the wholly wingless type usually have little color in the body, and the eyes are small. These forms rarely come aboveground or leave the burrows in wood.

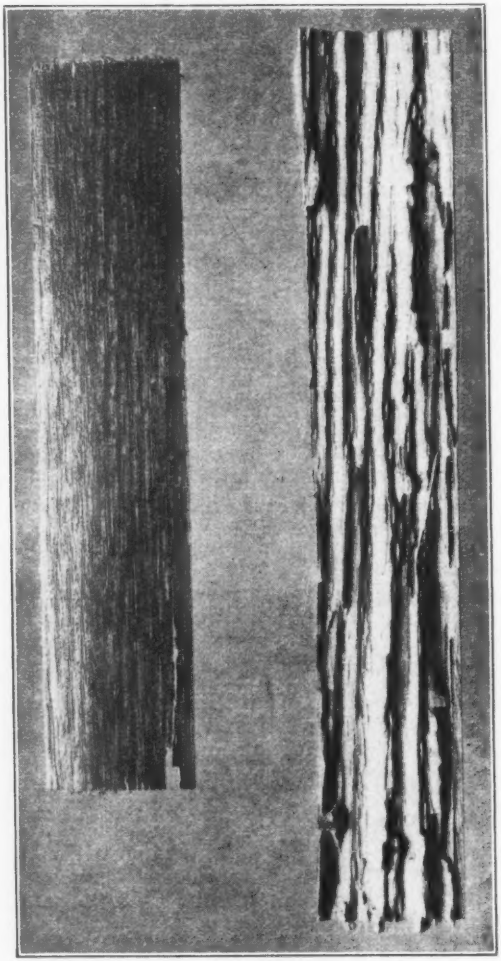

FIGURE 5.—Damage to oak flooring done by the common eastern subterranean termite *Reticulitermes flaripes*. Note that damage is not apparent on the upper surface.

The location of the queens in the colony depends upon the season of the year. During periods of intense heat or drought in the Plains or in arid or prairie regions the subterranean termites burrow deeply below ground or to a less depth under stones, cow chips, etc. During the winter in the colder climates they burrow below the frost line.

Whole colonies of subterranean termites migrate when conditions become unfavorable. The non-subterranean termites, on the other hand, are not able to leave the wood in which they have excavated their nests.

PREVENTING AND REMEDYING DAMAGE TO WOODWORK OF BUILDINGS

DESTRUCTION OF BREEDING PLACES ABOUT THE BUILDING SITE

If buildings are to be constructed on recently cleared woodland, decaying logs and stumps should be removed from the soil in the vicinity and burned. If, because of the presence of decaying wood and humus, the subterranean termites are numerous in the earth, the soil should be deeply plowed or otherwise

broken up and treated with chemicals to kill the insects. Effective poisons for this purpose are a 10-percent solution of sodium arsenite;[3]

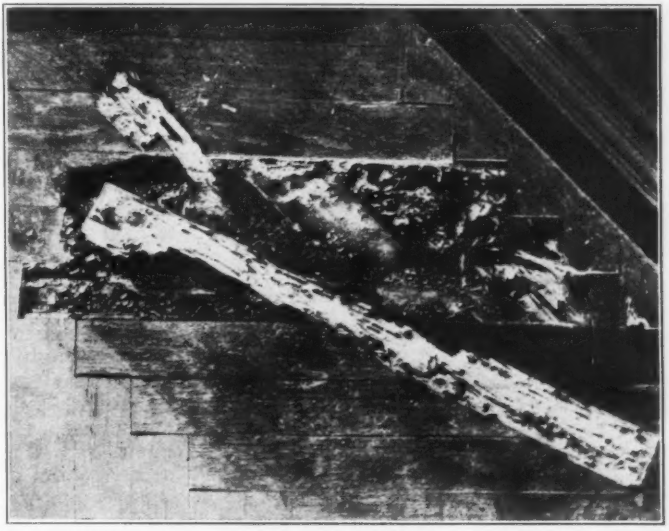

FIGURE 6.—Quartered-oak flooring damaged by the subterranean termite *Reticulitermes flavipes* in an infested building, Washington, D. C., 1915.

1 part coal-tar creosote and 3 parts kerosene oil (200 gallons per 1,000 square feet) (this mixture, if to be applied as a spray, should be strained through burlap before being used); 50-percent carbon disulphide emulsion (1 quart to 50 gallons water, applied at the rate of 3 pints per square foot), which is on the market ready for use; orthodichlorobenzene (100 gallons per 1,000 square feet). Live steam forced into the soil will serve the same purpose as the gases. Decaying fence posts, sidewalks, etc., should be removed and replaced with treated wood, concrete, stone, or other resistant substances; such decaying material would facilitate the formation or perpetuation of the termite colonies.

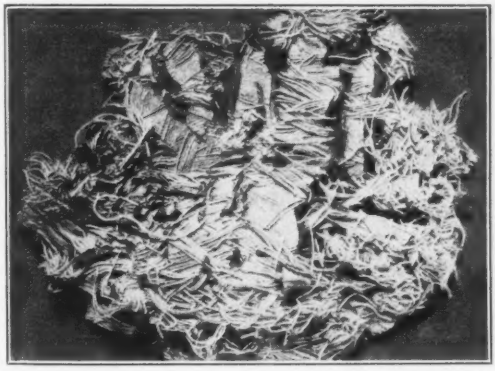

FIGURE 7.—Termite tubes through coarse baled cotton yarn stored on the floor of an infested building Greenville, S. C.

[3] This poison is caustic and should not be used near living vegetation.

PROPER CONSTRUCTION OF BUILDINGS

Termites will infest not only old buildings but also improperly constructed new buildings, and these are often badly infested. It is not the age of the building but the manner in which it has been constructed that renders it liable to attack.

INSULATION

Complete insulation from the ground of all untreated woodwork of buildings is the only effective permanent remedy against attack by subterranean termites, and the only relief from their presence. These insects must maintain contact with the ground to obtain the moisture necessary for their existence. When contact with their moisture supply in the earth is cut off, the subterranean insects in the damaged wood, no matter how numerous, soon die.

FOUNDATIONS, SUPPORTS, ETC.

To prevent subterranean termites from reaching the woodwork of buildings from their nests in the ground, the foundations of buildings should be constructed, if possible, entirely of stone, brick, concrete, or concrete and steel,[4] including the pillars in the basement or cellar. The walls, partitions, and flooring in the ground floor, basement, or cellar should also be of concrete. Wooden flooring can be laid over this concrete floor if desired. If the flooring is to be of concrete, the concrete should be laid on a gravel base.

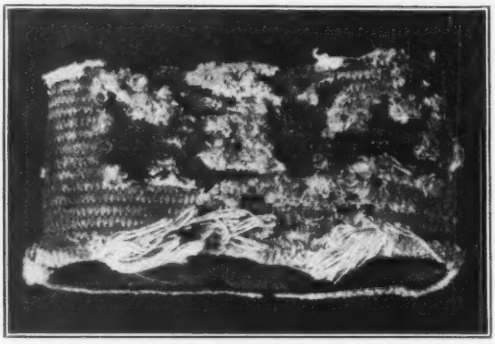

FIGURE 8.—Cotton jacket of rubber-lined fire hose from infested building in Missouri, damaged by subterranean termites (*Reticulitermes* sp.).

In buildings where stone, brick, or concrete foundations are impracticable, timber impregnated with coal-tar creosote should be employed, and no untreated wood should come in contact with ground which may be infested with termites. Wood to be protected from termites should be impregnated with coal-tar creosote by either the cylinder-pressure or the open-tank process.[5] The open-tank process is simpler, can be made to give satisfactory results where properly used, and can be operated by unskilled labor. If for any reason neither of the foregoing processes can be used, three coats of hot coal-tar creosote brushed on the wood, with sufficient intervals between brushings to permit each coat to dry, will be fairly effective. This method, however, is not generally recommended, since it will preserve the wood for only a few years.

[4] In the Southern States, especially in the subtropics, the more valuable permanent buildings should be constructed entirely of steel and concrete.

[5] Under Federal Specifications TT-W-571a, the Department of Agriculture recommends impregnation with coal-tar creosote for timbers to be used in contact with the ground before they are placed in the building; where timbers are to be used above ground and painted or finished, it recommends impregnation with zinc chloride, also before placement.

The supports of porches or steps should never be laid directly on the ground, but should rest on rock or concrete. Window sills and frames in the basement or cellar should be laid over concrete and the woodwork should not come in contact with the ground. The

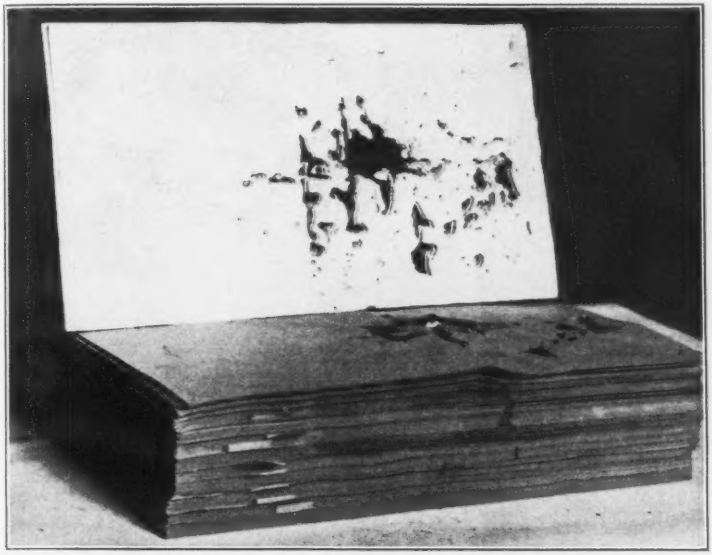

FIGURE 9.—Revenue stamps damaged by the subterranean termite *Reticulitermes flavipes* on infested flooring in the Bureau of Engraving and Printing, Washington, D. C., 1921.

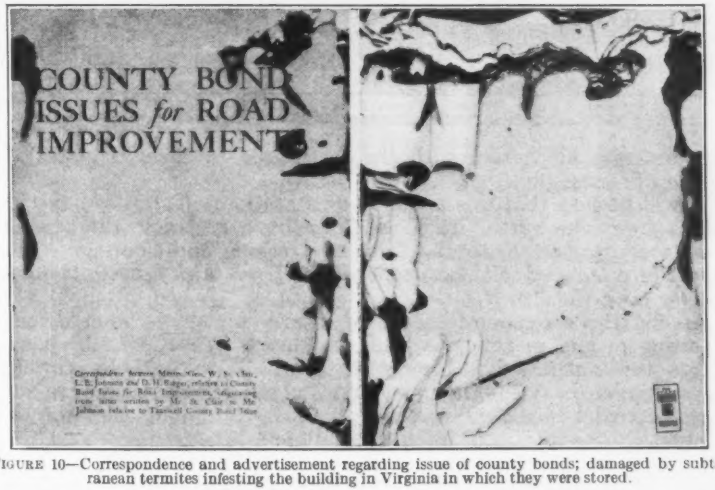

FIGURE 10—Correspondence and advertisement regarding issue of county bonds; damaged by subterranean termites infesting the building in Virginia in which they were stored.

supports of the woodwork of coal bins in basements or cellars should not be set on the ground, but should rest on concrete, not extending through the concrete into the soil.

CONCRETE FLOORING

Even in permanent stone or concrete and steel buildings the concrete flooring is often constructed improperly. Usually the base

FIGURE 11.—Damage done by the subterranean termite *Reticulitermes flavipes* to shoe stored on infested woodwork in a building in New York City.

of the concrete floor is a loose combination of coarse gravel or cinders and cement grout. This very rough conglomerate, even if several inches thick, has many cracks and large holes running through it Over this is laid a layer of solid concrete about 2 or 3 inches thick, of fine texture, in which untreated wooden sleepers are laid while it is still moist. These sleepers nearly or quite reach the coarse, open

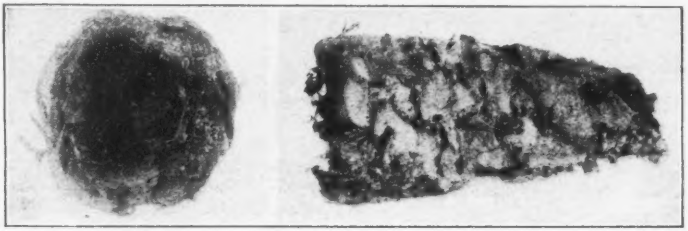

FIGURE 12.—Injury to carrots caused by the subterranean termite *Reticulitermes claripennis*, at Dallas, Tex.

conglomerate in contact with the earth, and to them is nailed the wooden flooring (fig. 16, *A*).

It will be seen that this is faulty construction. Termites have free access from the earth, in which they have galleries, through the porous conglomerate, to the untreated beams and flooring. *There should be a layer of solid concrete at least 1 inch thick between the grout and the wood* (fig. 16, *B*).

Among the commonest means of infestation are wooden sleepers or stringers laid in concrete while the latter is still soft, or placed before the concrete has been poured in. Termites enter through these wooden beams. Other common means of infestation are supports of coal bins extending through concrete and through the disintegrated lime mortar of brick walls.

TERMITE SHIELDS, GUARDS, OR METAL CAPS

Subterranean termites require constant access to soil moisture in order to attack wood. This requirement is supplied when wood is either in contact with the soil or when the termites can reach it

through covered, earthlike shelter tubes. These shelter tubes may be constructed over the face of stone, concrete, or brick foundations and along water pipes or similar surfaces, but they cannot cross a projecting metal barrier that is properly installed. Such a mechanical barrier in the form of a sheet of metal, or "termite shield," that will not rust or corrode should be placed over foundation walls and piers and around piping. It should extend horizontally at least 2 inches from the face of the foundation and should have a projecting edge of 2 additional inches bent downward at an angle of 45°. It is often

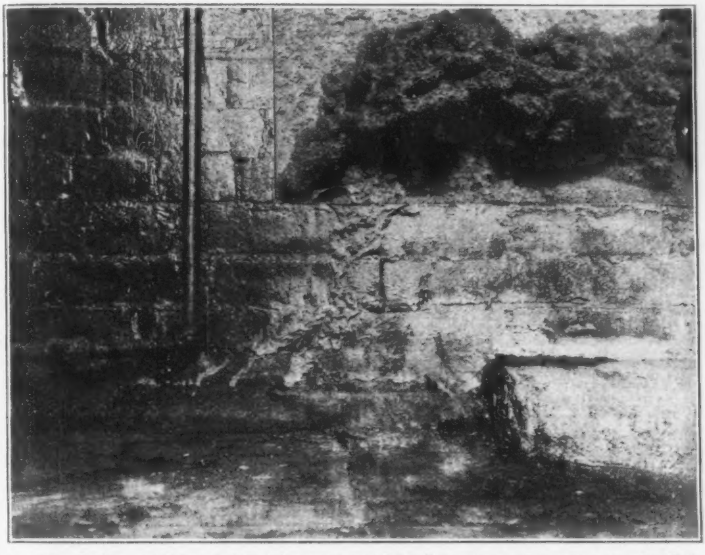

FIGURE 13.—Carton, earthlike, shelter tubes constructed by the eastern subterranean termite *Reticulitermes flavipes* over brick wall in dark, heated, damp basement; these tubes are used in passing over impenetrable substances. Inset, near view of tubes showing texture.

unnecessary to put this shield on all exposed exterior surfaces, but it is essential on interior surfaces (partially excavated portions of basements, closed-in sun parlors, porches, steps, etc.); and where the capping of the foundation wall is not effective or the mortar is of a poor grade or disintegrated, the shield should extend across and out beyond both surfaces of the wall. Where the outside projection is objectionable because of appearance a type of shield having a horizontal projection of one-fourth or one-half inch beyond the wall can be used. Such a projection compels the termites to deflect their path out into the open where they will be exposed in their endeavor to get around the shield to the wood above. Periodic inspections should be made to detect such attempts to circumvent the shield, but such inspections can be made at infrequent intervals because termites seldom build their tubes on the outside of the walls, The metal termite shields should be placed on foundations at least 18 inches above the ground.

This method is similar to that used in rat-proofing corncribs. It is effective and practicable where untreated timber is placed over masonry foundations.

Again, in the case of stone and steel buildings, the steel or stone pillars or piping extending down through the concrete floor to foundations in the earth often make infestation possible, owing to the fact that the concrete floor does not fit tightly about them. Overlapping strips of metal extending horizontally several inches from the pillars or pipes should be imbedded in the concrete floor in order to obtain a tight joint (fig. 16, *B*); or coal-tar pitch should be poured in to plug up the crevice or frame.

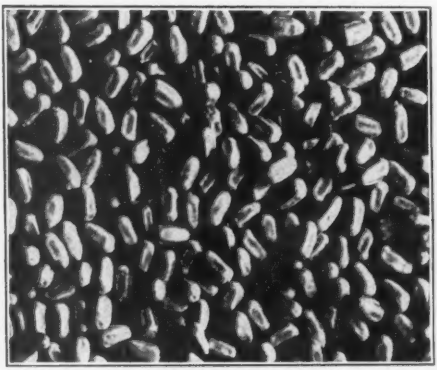

FIGURE 14.—Impressed pellets of excrement of nonsubterranean termites (*Kalotermes* sp.), which drop from infested wood. Greatly enlarged.

AVOIDING DAMPNESS

Dry foundation timbers and basement walls and flooring are important aids in rendering buildings safe from attack by termites. Dampness, warmth, and darkness are favorable to these insects. Concrete floors should be laid on a gravel base, which will prevent dampness and cracking. The points of juncture between concrete walls and wooden flooring should be filled in by rounding off the concrete at these places, since cracks often occur where the wall and floor join at right angles (fig. 16, *B*). Termites often come up through cracks between walls and flooring.

By mixing a heavy mineral residual oil with portland cement, a material is formed almost perfectly nonabsorbent of water and therefore excellent for use in damp-proof construction. Where the various patent or noiseless floorings are used on the ground floor they should always be laid over a concrete base, especially if they contain wood fiber as a constituent.

In no case should untreated beams be completely surrounded with mortar or brick; there should be a space around them sufficient to permit air circulation. Beams should not be set in earth or in moist concrete, but on rock or dry concrete, or in grooves in the latter.

Bungalows or frame buildings which have no cellar should be raised from the ground on stone, concrete, or brick foundations to a height which will allow light and air to penetrate beneath.

LIME MORTAR

Lime mortar sometimes disintegrates after a few years, and termites penetrate through the spaces thus left between the bricks, tiles, etc. Where lime mortar is used below the ground level (fig. 17) the walls should be faced with portland cement 1 inch thick, especially if untreated wood is to come in contact with the bricks.

USE OF CHEMICALLY TREATED WOOD FOR INTERIOR WOODWORK, FURNITURE, ETC.

In the Southern States, especially in the subtropics, in the more valuable permanent buildings the interior woodwork, furniture, etc., should be impregnated with preservatives, since nonsubterranean termites that attack wood directly are common in those regions. Zinc chloride and chlorinated naphthalene [6] are effective preservatives.

Wood-pulp or fiber products, such as the various wood-fiber processed or composition wall and insulating boards, for interior finish

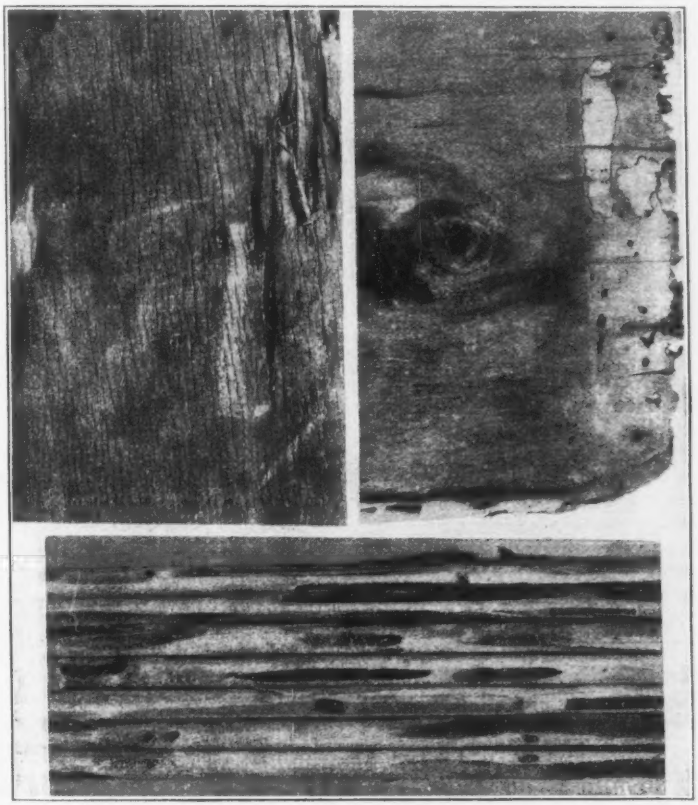

FIGURE 15.—The bottom of a bureau drawer, damaged by the nonsubterranean wood-boring termite *Cryptotermes brevis*, which occurs at Key West, Miami, and Palm Beach, Fla.

and substitutes for lath (fig. 18), or for exterior use, can be protected from attack by termites by adding certain poisons (such as coal-tar creosote at the rate of 2 gallons per 1,000 square feet) to the pulp or fiber laminated boards in the course of manufacture. Experiments with poisoning such products are not yet complete enough to warrant the giving out of definite general recommendations.

[6] This preservative is usually referred to as trichlornaphthalene and, as compared with other chemicals, it is really comparable to a technical product having naphthalene, monochloronaphthalene, dichlornaphthalene, and probably some of the higher chlorinations as impurities. Its melting point ranges between 190° and 210° F.—the specification under which it is sold.

CITY BUILDING CODES

Urban communities can do much to prevent termite damage by including in their building regulations or codes a few simple provisions which, if enforced, will protect houses from termites. Some cities now have such rules governing the construction of buildings, which have proved very helpful. The Bureau of Entomology will gladly supply information that will aid in drafting suitable regulations.

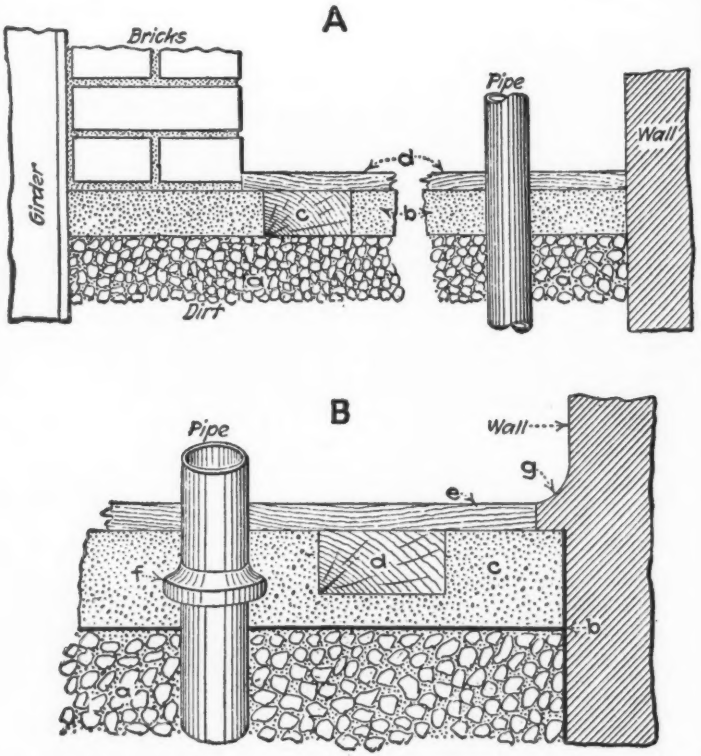

FIGURE 16.—*A*, Improperly constructed concrete flooring: *a*, Gravel or cinders loosely cemented with coarse concrete, 3 inches thick, but with many crevices and holes; *b*, solid, dense concrete, 2 inches thick; *c*, 2- by 4-inch untreated wood sleeper set in moist concrete over the grout; *d*, ⅞-inch pine flooring nailed to sleepers. *B*, Properly constructed concrete flooring: *a*, Gravel or cinders loosely cemented with coarse concrete, but with many crevices and holes; *b*, coal-tar pitch waterproofing ⅛ inch thick; *c*, dense concrete, 3 inches thick; *d*, 2- by 4-inch treated wood sleeper set in a groove in concrete which insulates it from termites in the earth; *e*, ⅞-inch flooring nailed on sleepers; *f*, metal collar around pipe which runs down through the concrete (this collar should be soldered to the pipe and embedded in the concrete); *g*, shoulder of concrete at point of wall and concrete floor to avoid a right-angle connection and consequent cracking.

The principal object is to keep all untreated wood from contact with the ground, where the termites live and from which they get their moisture. The regulations should, therefore, stipulate that no floors, sills, beams, clapboard, etc., of untreated wood may be laid on or in the earth and that untreated beams may not be laid in concrete without at least 1 inch of concrete underneath and separating it from the earth; that no lime mortar may be used in foundations or in cellar

walls where they are in contact with the earth, since termites are able to penetrate lime mortar [7] after some years' service; that all brickwork extending below the surface of the ground shall be faced and capped with concrete at least 1 inch thick; and, where nonsubterranean as well as subterranean termites occur, that only woodwork impregnated with preservatives be used for exterior and interior construction, unless it is impracticable to obtain such treated wood. Sun parlors, porches, steps, etc., in places where there is an earth fill, should be isolated from the main building. For further details see United States Department of Agriculture Leaflet 101, Injury to Buildings by Termites.

LOCATING AND TEMPORARILY ARRESTING THE DAMAGE

Although it may be difficult to eliminate termites and stop further damage by them, when once these insects have become established in

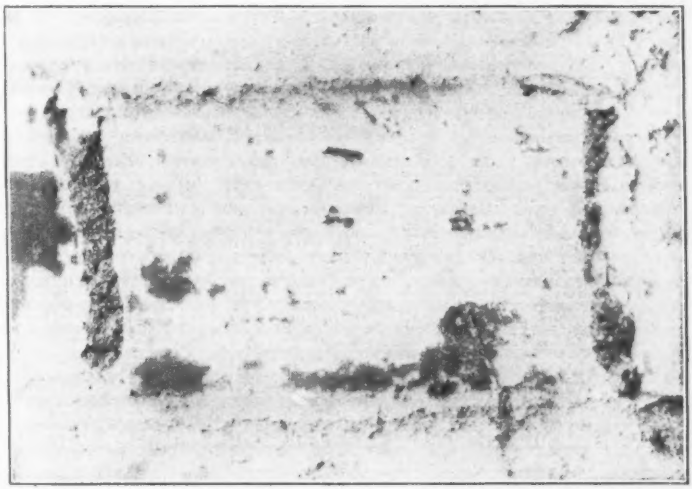

FIGURE 17.—Interior view of portion of whitewashed brick foundation wall of building, below ground level, showing shelter tubes of our common subterranean termite *Reticulitermes* sp., penetrating the disintegrated lime mortar. These termites came through the earth banked up against the exterior wall. To remedy this condition the exterior wall will have to be faced with concrete for some distance below the ground level.

the woodwork of a building, the approximate point of entrance should be sought at once by careful examination of all woodwork in contact with the ground. To do this, it may be necessary to tear up the foundations, flooring, and some other woodwork. The foundation timbers and interior woodwork found damaged should be removed, and the ground where they were set should be broken up and drenched either with orthodichlorobenzine or with a mixture composed of 1 part of coal-tar creosote and 3 parts of a light petroleum oil, such as kerosene, at the rate of 2 gallons per 10 linear feet, which will kill or at least temporarily prevent the further activity of termites at that point.

[7] The Bureau of Standards of the U. S. Department of Commerce recommends a mortar composed of 1 part portland cement to 3 parts of sand graded from fine to coarse, with no grains larger than will pass through a no. 10 sieve, to which may be added 10 percent by weight of the cement of some workability agent, such as hydrated lime, for use in locations where termites abound. Such a mortar, it is believed, will have the desirable properties of both cement and lime mortars and furthermore, will contain a sufficient quantity of cement to prevent the penetration of it by the termites (fig. 17).

INDICATIONS OF INFESTATION

The emergence of large numbers of the flying termites is an indication as well as a warning that the woodwork is infested, and the point of emergence indicates the approximate location of the infested timbers. Large numbers of the dead winged adults or of the discarded wings will usually be found near infested timbers following swarming. Frass and earth thrown out of crevices through which the insects emerge are also evidences of their presence. The presence of branching shelter tubes of small diameter, made of earth mixed with finely powdered wood, on foundation timbers or other woodwork, or over the surface of stone, brick, or other impenetrable foundation material (fig. 13), through which the insects travel from the ground to the woodwork, is another aid in locating infestations. These tubes should be broken off and the ground where they originate broken up and drenched with one of the liquids named in the paragraph under the heading, Destruction of Breeding Places about the Building Site (p. 7).

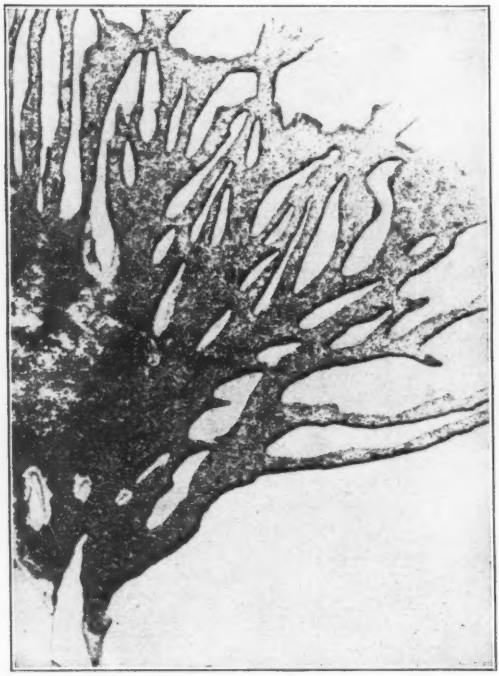

FIGURE 18.—Pressed wood-pulp tile mined by subterranean termites infesting the building, Biloxi, Miss.

In the case of the nonsubterranean termites, which infest wood directly, evidences that they are damaging wood are the impressed pellets of excrement (fig. 14) which are expelled from the wood. Other evidences are the holes, similar in size to BB shot, where the insects entered the wood (fig. 19).

KILLING THE WINGED ADULTS WILL NOT STOP THE DAMAGE

When efforts are made to prevent further damage by termites in buildings, it should be realized that the numbers of these insects may be constantly recruited from some undiscovered, outside, central colony. The destruction of the winged colonizing adults at the time of emergence, although beneficial in preventing the establishment of new colonies, out of doors, will not eradicate the insects infesting the woodwork. These winged adults are harmless indoors and will soon

die. Sweeping them up with a vacuum cleaner is a simple method of getting rid of them. The most destructive forms are the white, wingless workers, which remain within the wood.

DISCONNECTING WOOD FROM THE GROUND

Subterranean termites infesting beams or other wood will die if the wood is disconnected from the ground. Knowledge of this fact will save time and expense, especially in the case of old frame buildings, where extensive repairs would be unwarranted. Disconnecting untreated foundation timbers from contact with the soil will also cause the death of subterranean termites in the other woodwork, furniture, and stored material in the building, even if they have penetrated to the second or third floors. These timbers need not be removed or replaced unless seriously weakened structurally. However, if the wood is kept moist by some other means, such as water leakage, the termites will continue to work and thrive. This applies especially to damp corners of basements near outside water pipes, bathrooms, kitchens, and the like.

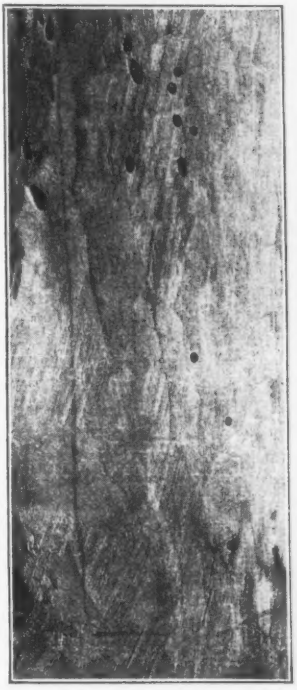

FIGURE 19.—Entrance holes of sexual, colonizing adults of a nonsubterranean termite (*Kalotermes hubbardi*) in wood of dead cottonwood tree in Arizona.

REPLACING WOOD WITH CONCRETE

Concrete floors and concrete baseboards should be substituted for wood. Untreated beams penetrating through concrete floors into the earth and the lower parts of door jambs and casings should be cut off at least 6 inches above the ground or floor and replaced with cement plinths, which should project one quarter inch beyond the jambs and casings. Metal strips should be sunk down from the woodwork into the concrete. Wooden thresholds, wainscoting, window sills, subsills, and stools in the basement or ground floor should be removed and placed on concrete (a layer of concrete between the earth and wood (fig. 16, *B*)) or replaced with concrete.

REPLACING WOOD WITH METAL

In basements and cellars steel rails or other structural metal work can sometimes be economically used to replace weakened timbers.

COMBATING TERMITES THAT ARE NONSUBTERRANEAN IN HABIT

Unlike the subterranean termites, nonsubterranean termites do not live in the soil, but fly to and attack wood directly. To combat such termites it is advisable to remove and replace the wood if the

damage is slight and localized. Where the wood has been seriously damaged, but not structurally weakened, saturate the infested wood with orthodichlorobenzene. The wood should be thoroughly saturated with this chemical, a rag or mop being used, dripping wet, or the liquid can be applied as a spray. Several applications may be necessary to kill the insects.

If orthodichlorobenzene is used as a spray, it is advised that the house be opened up before and for some time after treatment, since there is quite an odor to the chemical which may prove disagreeable in a closed room. Also, in spraying timbers overhead care should be taken not to let the liquid drip down, since it might slightly burn the face and hands and would be painful if it got into the eyes.

If the orthodichlorobenzene treatment is not practicable and the wood is too thick for the solution to penetrate, blow dry paris green, or the less dangerous although less effective sodium fluosilicate, by means of a bellows into holes bored with an auger into the infested wood; these holes should penetrate to the galleries of the termites. If, because of moisture, the powder becomes caked, the treatment should be repeated. Wood structurally weakened should be removed and replaced with chemically-treated wood [8] or strengthened with structural steel.

By far the greater and more serious damage to timber in the United States is caused by termites of the subterranean type. Department of Agriculture Leaflet 101, on the prevention of damage by termites in buildings, discusses in detail the control of subterranean termites infesting buildings.

PREVENTING AND REMEDYING INJURY TO LIVING VEGETATION

FRUIT, NUT, SHADE, AND FOREST TREES

Termites cause occasional but serious injury to individual living trees, shrubs, nursery stock, and grapevines. In case of shade trees the infestation may start as local at the base and extend more generally through the heart wood. A wise preventive measure is the removal of all loose wood which may afford them shelter, such as prunings, dead and dying trees, and the like, and untreated fence posts and similar material.

Termites are also occasionally a pest in orchards, not only in new orchards planted on freshly cleared land where there is such debris, but also, because of neglect, in old orchards, in both Florida and California.

Cleanliness in orchard and forest management is important. Since termites in the Southern States render unmerchantable the forest trees that have been killed by insects, fire, or disease, all timber from such trees should be utilized or removed as promptly as possible in areas where termites are common.

In the case of the pecan it is recommended that 2 or 3 cereal crops be grown on newly cleared land before the young trees are set out.

TREE SURGERY

Properly executed tree surgery sometimes is effective in repairing injury by termites to valuable old fruit and shade trees. .The termite-infested wood should be carefully cut out, and the dead heartwood should be given a brush treatment with coal-tar creosote. This

[8] See footnote 5, page 8.

treatment should not extend to within an inch of the living sapwood. Then the cavity should be filled with a suitable material.

COVERING SCARS AND PRUNED AREAS

To prevent infestation, care should be taken that the trees do not become scarred, especially near the base. Scars and all pruned areas should be treated with a mixture of one fourth creosote and three fourths coal tar. This mixture should not be allowed to come in contact with the living tissues at the edges of the bark; to protect them a shellac should be applied.

COMMERCIAL FERTILIZERS

Soil heavily manured will attract subterranean termites, since they can obtain food from the animal manure; commercial fertilizers should be used in preference in regions where termites are common in the soil.

YOUNG PLANTATIONS OR NURSERY STOCK

Injury to nursery stock from 1 to 3 years old will be more serious on recently cleared land and where decaying wood is abundant. Any debris in which the insects breed should be removed. In general the use of recently cleared land should be avoided in planting nursery stock. Earth used in banking should be free from rotten wood. Care should be taken not to allow the roots to dry out before being planted, as weakened stock is specially susceptible to attack; particular care should be given grafted stock.

INSECTICIDES

When valuable trees are infested but not yet dying, subterranean termites can be killed in the soil, if it is moist and not too compact, by breaking it up near the tree and pouring carbon disulphide on the earth at a distance of about a foot from the trunk, then covering the liquid over with earth. The gas from this liquid will penetrate the subterranean galleries of the termites. It is somewhat dangerous to plant life, and very large doses should not be used. *Care should be taken in handling this volatile fluid, as the gas or vapor from it is highly inflammable and explosive when mixed with air in certain proportions; no flame should be brought near it, and the fumes should not be inhaled, as they are poisonous.* There are indications that an emulsion of carbon disulphide, which is on the market ready for use, may prove more effective than carbon disulphide alone; as in the case of the disulphide itself, the earth is loosened up and the emulsion poured on, at least a foot from the tree. Carbon tetrachloride,[9] the gas from which is neither explosive nor inflammable, can be similarly used but is apparently not so effective as carbon disulphide. The gases from carbon disulphide and carbon tetrachloride, being heavier than air, will not readily rise.

Where nonsubterranean termites are infesting living trees, they can be poisoned with dry paris green in the manner discussed on page 18.

[9] Carbon tetrachloride is a thin, transparent, colorless, volatile liquid, which forms a gas with a pungent, aromatic odor. Like carbon disulphide, it is heavier than air. Although it is only about one half or one third as effective as carbon disulphide when used at the same dosage rate, it has the great advantage that its gas is neither explosive nor inflammable; there will be no fire risk attending its use in buildings.

VINEYARDS

In vineyards all dead or diseased vines should be removed. All exposed areas left by pruning should be painted with preservative coatings, and the prunings should be burned promptly. Nearby stands of tree windbreaks should be carefully cared for and kept free from infestation by termites. Trellis posts should be creosoted.

FIELD AND TRUCK CROPS

DEEP FALL PLOWING

Deep, late, fall plowing will be of value in breaking up the galleries and nests of subterranean termites on ground planted to field or truck crops. Irrigating the land, where practicable, will be effective; this can be done before planting the crop.

BURNING STUBBLE

Care should be taken not to plow under stubble which will serve as food for termites; it should be burned. The use of commercial fertilizers instead of animal manure is also recommended where subterranean termites are common in the soil.

ROTATION OF CROPS

As a result of the frequent stirring of the soil, rotation of crops will aid in preventing termites from injuring them. Plowing and fallowing are more practical than the use of insecticides in preparing the soil to prevent termite damage.

FLOWERS AND GREENHOUSE STOCK

Termites injure a great variety of flowers in gardens, as well as many plants grown under glass in greenhouses, where the warm, moist atmosphere maintained throughout the year promotes greatly the activity of the insects. Injury from termites is especially common where the plants are perennial and have woody stalks.

SOURCES OF INFESTATION

Heavily manured flower beds are a source of infestation to the stems of the flowers, as well as to the woodwork of buildings near by, if suitable protection is lacking. Termites can obtain food from the animal manure. Untreated wooden stakes used as supports of plants often become infested, and in time the insects attack the plants. Where greenhouses have already been built and termite damage is due to poor construction termites often attack old label sticks, the wooden uprights supporting wooden benches set on or in the ground, and the wooden bench bottoms and plant pots, and later attack the growing plants. The insects come up through the ground and form dirt galleries over the supports, or burrow up through the wooden bench legs and run galleries the full length of the benches. They enter the soil in the pots through the drainage holes and eat out the main stalk of the root, killing the plant very quickly.

PROPER CONSTRUCTION OF GREENHOUSES

Proper construction of greenhouses will practically safeguard plants growing in them from all injury by termites. Iron frames and concrete work should, wherever possible, replace bricks or woodwork.

In cases of infestation of old greenhouses, all wooden uprights supporting wooden plant benches should be sawed off, if set on or in the ground, and rested on stone, bricks, or concrete, above the surface of the ground. Proper repairing, including the removal of all infested wood, will prevent the plants from becoming infested in turn. Where woodwork is necessary the wood should be impregnated with zinc chloride or bichloride of mercury; it can be painted after treatment. Wood impregnated with coal-tar creosote cannot be used with safety in greenhouses.

AVOIDING STABLE MANURE

In flower gardens, especially those located near the woodwork of buildings, commercial fertilizer should be substituted for stable manure in order to protect not only the buildings but also the growing plants.

INSECTICIDES

Either carbon disulphide or carbon tetrachloride [10] can be used to kill termites in the soil if it is moist and not compact. These gases should not be used too near the infested plants, or the plants should be removed temporarily until the soil has been treated. Small holes should be made near the infested plants and a small quantity of the liquid chosen poured in and the holes immediately closed tightly with earth. Calcium cyanide [11] has also been found effective, but it should not be placed near living plants; it mixes readily with and enriches the soil and gives off an insecticidal gas which *should not be inhaled, as it is poisonous.*

An effective control may be found in the use of kerosene nicotine oleate or a 5-percent kerosene emulsion.[12] If the greenhouse benches are infested, but for any reason cannot be replaced, they should be soaked thoroughly with this emulsion, as should also the ashes and sand under the pots on the benches. This may be done by removing the potted plants from a section of the bench, spraying that section, and moving the pots on the bench to cover the treated area, thus giving access to another section. Potted heliotropes and geraniums have been treated directly with the 5-percent kerosene emulsion without injury to the plants, and the white ants in the soil of the pots were all killed. The soil should be wet down before this spray is used. This treatment should be given late in the afternoon and be followed early the next morning with a thorough syringing of the soil with water to wash out the surplus oil. It is important to remove all infested pots from the bench as soon as the infestation is noticed and to destroy the termites with kerosene emulsion.

[10] See footnote 9 (p. 19).

[11] 2 ounces of calcium cyanide to 1 square yard of ground is recommended.

[12] Kerosene emulsion is made as follows: Kerosene, 2 gallons; fish-oil soap, ½ pound; water, 1 gallon. Dissolve the soap in hot water and pour in the oil slowly, with constant stirring to emulsify. Dilution: If 37 gallons of water be added to the above stock emulsion it will give 40 gallons of 5-percent kerosene emulsion.

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